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A Preliminary Assessment of the Effectiveness of Flood Damage Reduction Measures in Canada

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A PRELIMINARY ASSESSMENT OF THE EFFECTIVENESS OF FLOOD DAMAGE REDUCTION MEASURES IN CANADA

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PREFACE

Floods are natural phenomena which have had significant social and economic impacts on populations located near waterways in both Canada and the USA. In order to reduce the damages caused by future floods, it is useful to assess key flood damage reduction strategies, how they have evolved, both politically and socially, and to provide some analysis on their effectiveness. A "Post-Audit of Flood Damage Reduction Programs" was one of six research projects to be undertaken as a follow-up to the Trilateral Workshop on Natural Hazards, held in Merrickville, Ontario in February 1995 (Etkin, 1995). Following the workshop, a proposal was developed to carry out a post-audit of the effectiveness of Flood Damage Reduction (FDR) programs in Canada and the USA.

The proposal, entitled "The Effectiveness of Flood Mitigation Measures: The Upper Midwest Floods" by Burnell E. Montz and Graham A. Tobin of Binghamton University, raised two fundamental questions in examining flood mitigation measures in the USA:

1) How are damages resulting from floods affected by the strategies used?; and,
2) Which strategies have been the most effective?

The proposal suggests looking at flood damage reduction strategies by conducting a detailed examination of their social, economic, ecological and hydrologic impacts.

In order to coordinate the Canadian and USA FDR research efforts, a working group committee on the flood damage reduction program was created by the Environmental Adaptation Research Group of Environment Canada (University of Toronto). A workshop was held on April 16, 1997 in Toronto. The workshop participants identified the evaluation of the current status of flood damage reduction in both Canada and the USA to be an essential aim of future research. They recommended that such an evaluation should address the following points:

1) How adequately regulatory bodies in Canada are equipped to deal with current and future flood problems;
2) How much has been achieved with respect to protection of natural functions of ecosystems;
3) The value of data collected to date (e.g., human occupancy on floodplains, economics, natural function of watersheds) and its applicability to policy processes;
4) The reason why useful information is often ignored in decision-making;
5) The accuracy of the data, and whether data accessibility could be improved by digitizing;
6) The frequency of, and need for, updating flood-zone maps, considering that insurance companies rely heavily on these to delineate flood-prone areas and set premiums; and,
7) The economic consequences of error, and the role of critical assumptions in affecting error estimates.

Funding and direction for the Canadian portion of the comparative assessment was provided by Emergency Preparedness Canada and the Environmental Adaptation Research Group of Environment Canada. During the first year of the study (FY 1997-1998), the preliminary assessment for Canada was conducted in three parts. The use of case studies in guiding research directives and providing a rapid assessment of the flood damage reduction program in Canada was identified as a valuable approach to do the evaluation. Four graduate students, under the supervision of their professors, (Dr. Slobodan Simonovic, University of Manitoba, Dr. Rob de

Loë, University of Guelph and Dr. Dan Shrubsole, University of Western Ontario, and Dr. Jean Rousselle, École polytechnique, Université de Montréal), gathered data for the Red River Basin in Manitoba, the Credit River in Ontario, and the Chaudière River in Quebec, respectively. The data gathered included: human occupancy of floodplains, the net economic value of floodplains, and the natural functions of watersheds for the periods 1970, 1980, 1990 and 2000. Each case study team also conducted a literature survey and created a list of contacts in order to survey the policy and state of practice of FDR in Canada.

The Manitoba case study initially reviewed the nature, causes and pertinent issues in flooding along the Red River. A brief history of flood events was also included. The report then provided information relevant to a discussion of flood mitigation strategies by briefly discussing topics such as damage assessment, agricultural activity, federal flood mitigation policy, and provincial responsibilities for flood management in Manitoba.

The Ontario case study was considerably narrower in focus. Instead of evaluating all of the watershed functions identified by Montz and Tobin, the researchers focused on the natural functions research questions. A content analysis of policies relevant to the Credit River watershed was conducted. This was followed by a more detailed field-level analysis in three communities within the Credit River watershed.

As a first step, the Quebec case study reviewed the Canada-Quebec agreement on flood damage reduction, and the Quebec policies resulting from those agreements. In order to assess the effectiveness of the various policies, a case study of the Chaudière River Basin was also undertaken.

A fourth case study in Canada was initiated during the second year of the comparative assessment (FY 1998-1999). This study was conducted by a graduate student under the supervision of Dr. Jean Rousselle, École polytechnique, Université de Montréal and focused on the effectiveness of flood damage reduction measures in the Greater Montreal region.

Reference:
Etkin, D. (ed.) 1995. *Proceedings of a Tri-lateral Workshop on Natural Hazards held in Merrickville, Ontario, February 11-14, 1995.*

Disclaimer

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By: Esther Roy, École Polytechnique de Montréal, Dr. Jean Rousselle, École Polytechnique de Montréal and Jacinthe Lacroix, Public Safety Department, Québec government

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By: Simon Forget, Benoît Robert, and Jean Rousselle, École Polytechnique de Montréal

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CASE STUDY: EFFORTS IN FLOOD DAMAGE REDUCTION IN THE RED RIVER BASIN - PRACTICAL CONSIDERATIONS

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Abstract

This report reviews the nature, causes, and pertinent issues in flooding along the Red River. There is also a brief history of flood events. Key structural and non-structural measures in the Red River Basin are examined, including a review of how these measures have evolved, and the most pertinent issues related to those measures today, particularly in the wake of the 1997 flood.

The report concludes that there is a shortage of comprehensive information that can be used to quantitatively assess the effectiveness of flood mitigation strategies in the Red River Basin. Information is scattered across different levels of government and departments and is not well-organized. Nevertheless, some general conclusions can be made.

It is evident that without the current flood control system protecting the city of Winnipeg, losses from floods since the late 1960s would be much greater in magnitude. However, there is a lack of concrete information on the effectiveness of structural measures in the upper Red River Valley. The long-term consequences of numerous home and community dikes on water movement in the rural landscape are unknown and warrant further investigation.

Of the non-structural flood damage reduction measures, poor enforcement by authorities and inconsistent application of land use regulation by municipal governments has greatly reduced the effectiveness of this strategy in the Red River Basin.

The flood proofing programs sponsored by the federal and provincial governments in past years have had a positive effect. Both communities and individuals who floodproofed to the 1979 design flood level suffered less damages overall during the 1997 flood. However, flood proofing has its limitations, particularly when water levels exceed the standard 100-year level or unpredicted overland flows occur.

1. INTRODUCTION

The proposal entitled The Effectiveness of Flood Mitigation Measures: The Upper Midwest Floods by Burnell E. Montz and Graham A. Tobin raises two fundamental questions in examining flood mitigation measures, i.e. how are damages resulting from floods affected by the strategies used?, and which strategies have been most effective? The proposal suggests looking at flood damage reduction strategies by detailed examination of their impacts---social, economic, ecological, and hydrologic.

While the above goal is well beyond the scope of this project, this report does attempt to look at key flood damage reduction strategies in the Red River Basin, how they have evolved both politically and socially, and provide some cursory information on their effectiveness.

To that end, this report initially reviews the nature, causes, and pertinent issues in flooding along the Red River. There is also a brief history of flood events. Secondly, the paper provides information relevant to a discussion of flood mitigation strategies by touching briefly on topics such as damage assessment, agricultural activity, federal flood mitigation policy, and provincial responsibilities for flood management.

Key structural and non-structural measures in the Red River Basin are examined, including a review of how these measures have evolved, and the most pertinent issues related to those measures today, particularly in the wake of the 1997 flood.

Finally, in the Conclusion, there are a series of observations on the effectiveness of structural and nonstructural measures in the Basin, and some key problems requiring consideration. The conclusions offered are solely those of the authors and do not necessarily reflect the opinions of sources of information referenced.

2. FLOODING IN THE RED RIVER BASIN

2.1 Description of the Red River and its Basin

The Red River is a large meandering river that flows north through parts of eastern North Dakota, northeastern Minnesota and southern Manitoba to finally end in Lake Winnipeg. It is part of the Hudson Bay drainage system. It actually originates about 550 miles south of Winnipeg in the northern United States. The river, and its surrounding valley, occupy a fraction of an area once occupied by a glacial lake—Lake Agassiz. The glacial lake existed during a time span ranging from about 12,000 to 7,500 years ago (Krenz and Leitch, 1993). The slope of the river is very gentle with an overall slope of only one half a foot per mile, and low water flow velocities in general. Zero flow conditions have even been recorded over the years at some locations. In contrast, during flood events, there have been flows on the Red River nearing 100,000 cubic feet per second. The flows of the Red River are thus highly variable, depending on conditions.

This normally slow river does not cut very deep channels, making it relatively easy in flood conditions for there to be an uncontrolled overbank flow which spreads over a wide area; here it may remain for days or even weeks.

The Red River has several tributaries, the most significant of which is the Assiniboine River; where the two rivers drain together the drainage area of the Red River increases from 48,000 to 111,000 square miles. The Assiniboine River flows out of the province of Saskatchewan in an easterly direction, and into the Red River at the center of downtown Winnipeg. It drains an area of 63,000 square miles to the west of the city. At some westerly points the Assiniboine River is confined to a deeper channel but by the time it approaches Winnipeg the slope of the land is sufficiently reduced to prevent development of deep channels to contain the water. Thus the Assiniboine too is subject to easy overflow near the junction of the two rivers and the excess water flows overland into the Red River and Lake Manitoba. This increases the flood risk to the most highly populated area of the Red River Basin, i.e. Winnipeg and surrounding area.

The area commonly referred to as the Red River *Basin* consists not only of the old glacial bed (i.e., the Red River Valley) but also about 28,000 additional square miles with a total area of close to 45,000 square miles. Of this area, about 5000 square miles are in Canada and 40,000 square miles in the United States. The drainage area of the Basin is shared by North and South Dakota, Minnesota and Manitoba – areas of 47, 1, 41, and 11 percent respectively (Krentz and Leitch. 1993). On the eastern side of the Red River drainage basin, landscape is so level that wetlands drain to either side. On the western side, natural drainage systems have been interrupted in places by deposits from glaciers causing surface water to collect there rather than drain, until it evaporates or seeps away. The type of soil in this region also contributes to flooding because, while topsoil is rich, beneath it lies anywhere from 4 to 60 feet of largely clay, and clay has a low absorptive capacity. Water tends to sit on the surface for extended periods of time.

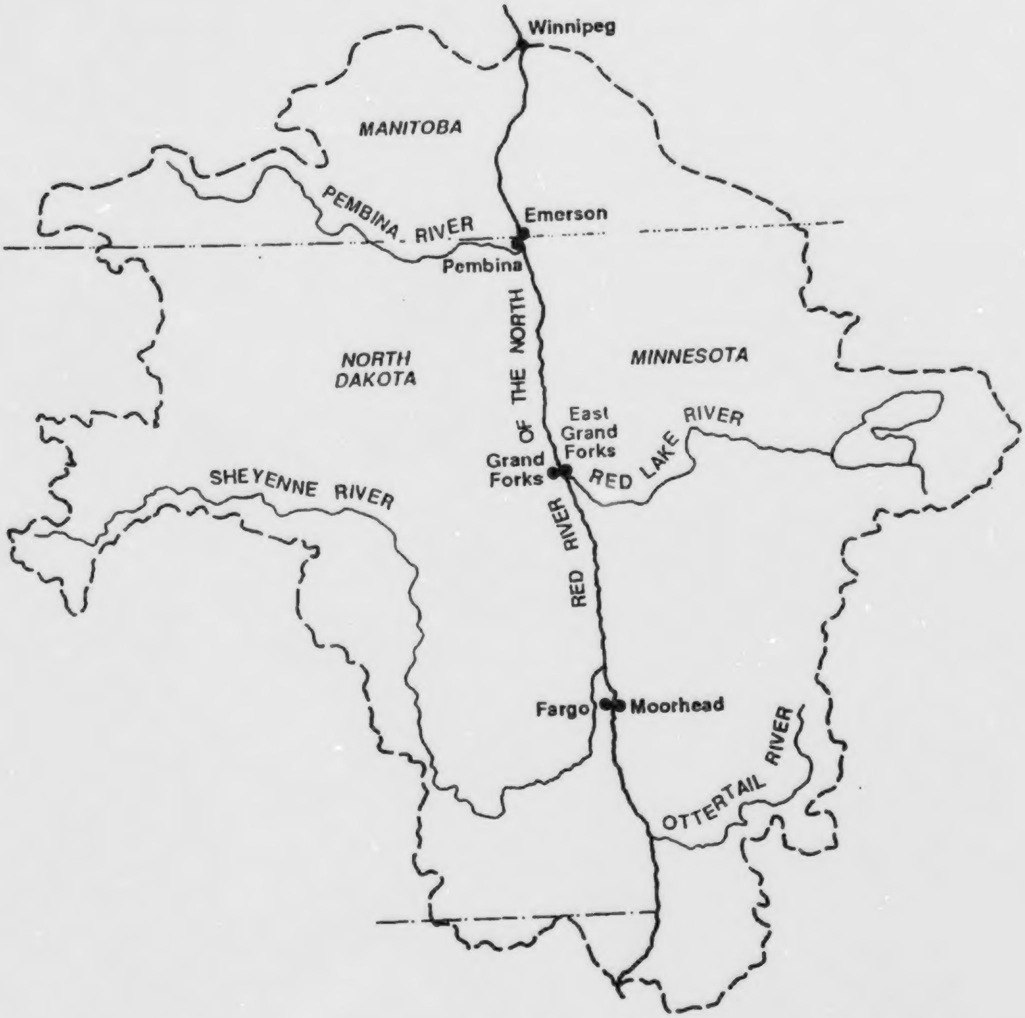


Figure 1 - The Red River Basin (Source: Krentz and Leitz, 1993)

2.2 The Causes of Flooding in the Red River Basin

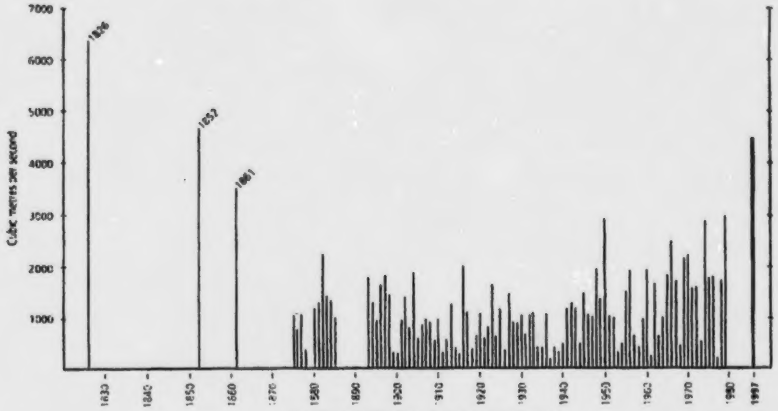
There are several factors which contribute to the flooding potential of the Red River, and the two major types of flooding which are apt to result. These two types of flooding include the more common stream bank overflow and the more unusual scenario where runoff (due to snow or rainfall) gets trapped on sections of lands due to barriers posed by raised roadways and exacerbated by plugged culverts and ditches (Krenz and Leitch, 1993).

Of the factors in the Red River Basin which contribute to flooding, one is clearly the factor of area topography --- it is relatively flat, with slow moving water and consequently longer duration floods. Floods in this region approach slowly, with days or even weeks warning. These longer duration floods provide more opportunity for evacuation of people at risk; however, they are likely to increase property damage. Research conducted by Edward A. McBean *et al.* (1988), in attempting to quantify the increase in flood damages from longer duration floods by detailed analysis of depth damage curves under different flood characteristics (such as duration) revealed a total damages increase in the order of 6% if the flood duration exceeded even 24 hours. In 1997, the Red River flood waters remained in people's homes for more than one week in many instances.

The flat topography of the Red River Basin and the shallow river channel are also a problem because of the large number of sub-basins which feed into the basin–more than 20 sub-basins by most estimates. These many sub-basins can produce a heavy runoff which can easily exceed the river channel's capacity. Of particular problem are overland flows from the Red River's tributaries. Overland flows are also difficult to monitor and forecast. The International Joint Commission on the Red River Basin (IJC, 1997) stated that much of the devastation caused to some communities in the 1997 flood (e.g., Grand Forks - East Grand Forks, Ste. Agathe and Grande Pointe) was greatly increased by overland flooding. This type of overland water movement is more difficult to predict and makes estimation of crest levels more uncertain. Overland flooding in the Red River Basin, under adverse weather conditions, can result in a flooded area of over 1000 to 2000 square miles which can then last from 4 to 6 weeks (Krenz and Leitch, 1993).

Weather is a pivotal factor in determining if flood conditions will occur each year along the Red River. In general the climate of southeastern Manitoba is classified as *sub humid* to *humid continental* with resultant extreme temperature variations. Annually, most of the precipitation received is in the summer rather than the winter. Approximately ¾ of the 20 inches (50 cm) of annual precipitation occurs from April to September. Consequently, most years spring melt is well managed by the capacities of the Red River and its tributaries (Bumsted, 1997). However, periodically weather conditions exist which instead promote widespread flooding through the valley. The most troublesome conditions (especially when most or all exist in the same year) are as follows:

a) heavy precipitation in the fall
b) hard and deep frost prior to snowfall
c) substantial snowfall
d) late and sudden spring thaw
e) wet snow/rain during spring breakup of ice



RED RIVER SPRING PEAK FLOWS AT WINNIPEG
NOTE 1: For period 1969-79, computed natural flows as computed by WRD, Manitoba.
NOTE 2: For period prior to 1913, data from Red River Basin Investigations

Figure 2 - Red River Spring Peak Flows (Source: Bumsted, 1997)

Another factor in the Red River Basin which can contribute to flooding is the unusual south to north flow. As noted previously, a large majority of the area of the Basin lies in the United States. Weather and thaw conditions in the southern reaches of the river thus affect the timing, amounts, and duration of water flowing northward. However, it is important to note that flood conditions have occurred to the south without northern flooding and vice versa depending upon conditions.

Ice jams are a factor that can also add to flood threat in the Red River Basin. Ice jams both in the main stem and in tributaries can cause water to back up, elevating flows temporarily, or causing overland flows. Sudden release of ice jams can also cause dangerous surges of water, with resultant damage.

The Red River floodplain has natural levees at points both on the main stem and on some tributaries. These levees (some 5 feet high) have resulted from accumulated sediment deposit during past floods. Because of the flat terrain, when the river overflows these levees, the water can spread out over enormous distances without stopping or pooling, exacerbating flood conditions.

A final note about definition of the so-called Red River "floodplain". This description is somewhat arbitrary, at least for the purposes of management of the flood prone area. The standard typically set in the U.S. for application in land use regulations has been the 100 – year flood level; now in Canada it is the 1997 flood level plus two feet. The use of particular levels in land development policy and various land use and water management regulations is an important consideration in flood damage reduction. One might question the use of levels known to be less than the highest flood levels by historic account; this is clearly the case in Winnipeg where the 1826 flood remains the highest on record. The current tendency to adjust levels upwards with successive floods may seem reactive rather than proactive, and constitute a short-term rather than long-term approach to damage reduction.

2.2.1. Agricultural Land Use and the Issue of Drainage

Before a more comprehensive look at flood mitigation in the Basin, a few comments about agricultural land use and flooding is warranted because of the large amount of agricultural activity in the area.

There has been an extensive and expanding drainage system instituted in the Basin to help agricultural production by increasing arable land. The purpose of agricultural drainage is to remove, during the growing season, water in excess of the needs of crops and to prevent sitting water from reducing yields. However, the contribution of drainage activities, if any, to flooding and damages is both a concern and a source of disagreement.

Drainage may contribute to erosion and hence flooding. There are also often impacts to downstream landowners when new drainage measures are instituted. There are concerns particularly about the contribution of artificial drainage systems to unexpected overland flows during flood conditions. Overland water flows can cause water to sit in the Basin for four to six weeks after a flood. In acknowledgement of the many unanswered questions related to the impact of drainage and land use in general on flooding, the National Hydrology Research Centre is now conducting a study in Manitoba and Saskatchewan to look at this issue.

It is therefore evident that drainage should be considered as part of larger water management plans. Local impacts should be monitored and addressed in local watershed management, and considered in local subdivision and development planning. The provincial government realizes that the enforcement of drainage regulations and required licensing is a problem and is now urging local governments to prioritize this issue in water management.

In essence, much agricultural land use in the valley is possible because of man-made drainage works. During a flood significant economic losses occur because of flood water on agricultural land. The types of flood losses related to agriculture are due primarily to delayed seeding, reduced yield and subsequent loss of income from agricultural production. It should, however, also be remembered that much of the fertility of the Basin is a result of the periodic floods which replenish the soil with additional nutrients.

In 1997 the impacts of flooding on agriculture were numerous in addition to the above. Many dugouts used by farmers for various purposes, including hogs and poultry, were contaminated by chemicals or high bacteria levels. About 8,000 cattle, hogs, poultry, and sheep died in the Red River Basin, most at the onset of the flood in the U.S. In Canada some animals had to be evacuated; other farmers remained on their farms and made enormous preparations. A few grain farmers managed to move stored grain. Much stored grain was contaminated by flood waters and ruined; agricultural chemical storage facilities also posed a risk as flood waters released chemicals into the environment. Increasingly, the need for producers to flood proof their individual properties is evident. This also raises the question of where will the diverted water go, and who will be impacted?

2.3 Flood History

Serious floods on the Canadian side of the Red River Basin were experienced in the years 1776, 1826, 1852, 1861, 1916, 1950,and 1979; less serious floods occurred in 1882, 1897, 1904, 1948, 1956, 1966, 1969, 1974, and 1996.

Anecdotal accounts of the Red River Valley make it abundantly clear that extreme floods were experienced as far back as the 1700s. The flood of 1826 is the largest flood on record; it was significantly larger than the devastating 1997 flood. A sudden thaw in April of 1826, followed by ice jams on the river and simultaneous heavy rainfall, had water on the Red River rise 5 feet downtown in just twenty-four hours. Preservation of life took precedence over preservation of property, thus losses were enormous. Whole houses were carried by the river. The estimated maximum flow was 260,000 cubic feet per second by the record. The water apparently took over one month to recede completely (Bumsted, 1997).

A large flood followed in 1852, probably partly due to heavy precipitation throughout the 1840s. From 1852 to 1861 there were some dry years followed by heavy precipitation in 1860 and 1861. In 1861, water inundated the settlement at present day Winnipeg with some damage to homes, but few cases of extreme destruction.

Although the 1882 flood was not one of the largest floods, it came at a time when real estate preferences had shifted. Instead of avoiding river property, people were now building expensive homes right along the river.

The 1897 flood was sizeable, although well below 1826. Maximum discharge at the Redwood Bridge was 64,500 cfs. While this flood was very damaging south of Winnipeg, the city itself suffered only minimal damage.

The flood of 1904 came after the first water management project in the Red River Valley had been established. It consisted of reclamation of land for human uses through a series of drainage ditches which altered the natural flow of water. The flood itself was largely the result of a blizzard in the U.S. portion of the Valley. Ice jams ultimately occurred and dynamite was used to break up jams in the city. Flooding spread through lower lying areas of the city.

The 1916 flood followed a period of quite rapid population growth; Winnipeg had 163,000 people, many in residential areas adjacent to the two rivers in the city. Up to 10,000 residents were evacuated from Winnipeg as parts of the city were under water. Hundreds were evacuated from the upper valley.

The 1948 flood was the result of a cold winter, heavy snowpack and sudden spring thaw. Agricultural damage alone was close to a million dollars. The river reached 23.4 feet above datum (the natural channel capacity of the Red River in Winnipeg is only 18.0 feet above datum). Emergency diking in the city was extensive. Flood fighting and relief were coordinated for the first time, not by government but by a private agency, the Red Cross.

A pivotal event in Red River flood history was the 1950 flood which was classified a great Canadian natural disaster. A very cold winter and heavy snowpack in the United States, combined with heavy rain during runoff, were the primary causes. All towns within the flooded area in the upper valley had to evacuate. Over 10,000 homes were flooded in Winnipeg and 100,000 people evacuated. A plan to evacuate all 350,000 people in Winnipeg was prepared, although luckily not used.

Both provincial and federal governments, albeit reluctantly, began formally to contribute financially to flood relief restoration for the first time. And large-scale structural flood damage measures were considered and later implemented to protect Winnipeg and some valley communities.

Spring 1956 brought a flood threat and intense flood preparation; luckily a turn for the better in weather saved Winnipeg. Most damage was along the Assiniboine River. Similarly, in 1966, ominous weather in early spring seemed to indicate higher threat than actually materialized.

The 1969 flood was the first after the Floodway was complete, and the gates were used for the first time. There was virtually no flooding in Winnipeg although there were claims that gate operation worsened the situation immediately south of the Floodway. This was the pattern through the 1974 flood where levels would have reached 31 feet in Winnipeg (higher than the 1950 flood) if not for the Floodway. More than 2500 rural residents did evacuate.

The large 1979 flood was primarily the result of a rapid thaw and wet spring. Half of the upper valley evacuated. Homes just south of the flood control system were very hard hit yet again. Winnipeg was largely spared.

The 1980s in general were a drier decade, although the Floodway was in fact employed 20 times from 1969 to 1997. Serious flood threats occurred in 1991, 1994, and 1996 with damages to some rural residents and communities.

The 1997 flood was a true test of the flood control system throughout the valley. Extreme snowpack (98th percentile), extreme cold north and south of the border, high topsoil moisture, unfavorable time of runoff, and an April blizzard combined to cause the inundation. The peak discharge at Emerson, Manitoba (at the border) was 130,000 cfs; in the 1950 flood it was 94,000 cfs. At the Floodway Inlet (just south of Winnipeg) peak was 158,000 cfs compared to 94,000 cfs in 1950. Floodwaters at the Inlet had actually crested 1.5 to 1.7 feet higher than the forecast range pronounced; unexpected overland flooding was a major contributor to the error in forecasting, and ultimately increased damages.

The 1997 flood was the highest recorded this century. An estimated 1840 square kilometers of land was flooded as the Red River rose 12 meters above winter levels. Structural measures previously discussed such as the diking systems and the Red River Floodway are known to have prevented enormous losses, as did emergency diking. Estimates of those prevented damages run as high as $6 billion. Actual damage claims are currently at $150 million, with $250 million in payouts anticipated. Eight valley towns with ring dikes remained dry; however, one town, one urban-fringe community, and numerous farm properties were flooded with subsequent damages.

2.4 Flood Damage Assessment in the Red River Basin

Table 1 provides an overview of damages resulting from past floods in the Basin according to available sources of information. These figures are in no way comprehensive because there is no detailed accounting of what the money for damage mitigation was specifically used for in many instances, and in floods such as in 1950, 1979 and 1997 non-governmental organizations such as the Red Cross, and other charity organizations often made major contributions for items not normally compensated, about which there is also little information.

In 1997 more information as to compensation/restoration money is available. Damage claimants are generally compensated for the following (although not necessarily limited to): dwellings and some contents, outbuildings, stored grain, fencing, bailed hay, driveways, machinery, erosion damage. Municipalities are compensated for such things as roads, washouts, bridges, culverts, and flood fighting costs -including some labour costs in excess of municipal employees' regular salaries. These types of damages are reflected in the 1997 values in Table 1. The Emergency Measures Organization handles these claims, and communicates with the federal government about cost-sharing flood fighting and recovery costs. The provincial EMO does, in fact, provide compensation for some items which the federal government will refuse to contribute towards (eg. Church losses). Some damages, like personal hardship, wage loss, business losses etc. are not covered by the EMO program. As noted in Table 1, about $150 million has been paid out to date in individual and municipal claims, but approximately $250 million is anticipated in total. (Further discussion of the EMO program appears under Flood Recovery).

In 1997, the Federal government instituted a Job and Economic Restoration Initiative (JERI) to aid businesses and farms in recovery. To date, $25 million has been disseminated, cost shared 50%-50% with the province. More payouts are anticipated.

Table 1 Flood Damage Approximations – 1950, 1966, 1979, 1996 and 1997 Floods

Flood Year	Amount Paid in Assistance	Source of Monies	Paid For		Comment
			Damages	Other Assistance	
1950	$12.5 M	Federal	X		
	$21.0 M	Province	X		Includes home, farms & small business
	$19.0 M	Private Donations			To supplement for uncovered damages
1966	$10.0 M	Province & Federal (per cost sharing agreement)		Flood fighting & response	Initial predictions very high, so flood fighting costs inflated
	$1.4 M	Province & Federal (per agreement)	X		
Floodway System Completed					
1979	$7.8 M	Province & Federal (per agreement)	X		Includes individual and municipal damage
	$7.1 M	Province & Federal (per agreement)		Flood Proofing	
1996	$12.0 M	Province & Federal (per agreement)	X		Damages largely in upper valley. Includes individual and municipal damage

1997	$150.0 M (anticipate $250.0 M)	Province & Federal (per Disaster Financial Assistance agreement)	X		Includes c.5100 individual and c. 60 municipal claims*
	$12.0 M	Province & Federal		Flood Proofing (additional Provincial money anticipated)	includes c.2450 private applications*
	$2.0 M	Province		Temporary housing	more expenditures anticipated-70 families still need housing*

* information as of March 1, 1998

Note: The above information was gathered from multiple sources. Information for 1997 flood received from EMO and Manitoba Government News Releases, February, 1998.

3. FLOOD CONTROL POLICY

To provide a context for understanding the evolution of federal-provincial policy on flood damage reduction, a cursory overview of the three major pieces of federal legislation related to the topic will be done. These pieces of legislation were responsible for influencing the nature of federal-provincial agreements and activities for flood damage reduction in Manitoba. A brief synopsis of the major authorities with jurisdiction related to flood mitigation in Manitoba will also be given.

3.1 Three Federal Acts

- Canada Water Conservation Assistance Act
- Canada Water Act
- Flood Damage Reduction Program

The first of these acts, the Canada Water Conservation Assistance Act came about in 1953. It was recognized that previous legislation, including the transfer of jurisdiction over natural resources to the provinces, was not comprehensive and jurisdictional disputes between the federal government and the provinces continued. A more comprehensive legislation to deal specifically with water resources was needed.

3.1.1. Canada Water Conservation Assistance Act (1953)

As the first actual water resources Act, it was intended to provide (to the provinces) federal financial assistance for the construction of "works" designed to conserve or control water. The Act stated that the federal government would contribute up to 37.5% of the cost of the works, provided the contribution of the federal government was not greater than that of the provinces.

3.1.2. Canada Water Act (1970)

Superceding the previous Act, the Canada Water Act outlined the nature of federal involvement in water resource management and water quality programs. It allowed for federal-provincial agreements to conduct research, formulate comprehensive water management plans, and develop water management projects. It differed from the previous Act because it focussed not on "works" alone, allowing for consideration of non-structural water management alternatives. It also allowed for consideration of economic, social and environmental objectives, and solicitation of ideas from people affected by the management plans. There was a broader planning perspective. looking at larger geographical areas and wider impacts.

Concerns which the Act hoped to address through more comprehensive planning included: reducing flood damage costs, and reducing "income transfer" from the general public to floodplain dwellers in the event of floods.

3.1.3. Flood Damage Reduction Program (1975) - umbrella agreement still in effect until 1999

The primary objective of the Flood Damage Reduction Program was to reduce escalating flood damage costs; it came about because much of the increasing damage in the 1970s, it was recognized, was due to *new* uncontrolled development in floodplains. The *first* goal was to discourage development in high-risk floodplains.

To identify these high-risk areas, the program included a flood mapping agreement, and a public education component; this would allow the " designated flood areas" to be formally determined, mapped, and shared with the public, to discourage further inappropriate development. For each designated area, provincial and federal governments agreed to the following provisions: 1) they would not build, approve or finance inappropriate development; 2) they would not provide flood disaster assistance for such development built after the designation as flood-prone; 3) provincial authorities would *encourage* local authorities to zone on the basis of flood risk.

The first provision of the above legislation has been somewhat successful in Manitoba. Projects have been refused funding by federal and provincial government because they were inappropriate for the level of flood risk in the proposed location. Others were approved subject to meeting certain building criteria. Canadian Mortgage and Housing (CMHC), in particular, has turned down development projects which don't measure up under scrutiny (Information as to the number of projects rejected could not be obtained). However, the numerous municipal governments in the Red River Basin have much autonomy with regard to development in their area; hence, there are significant differences in their flood damage reduction objectives.

The second provision has not been enforced in Manitoba; no individual or business has been refused assistance (e.g. 1997) because their structure was not appropriate or failed to meet certain flood-proofing standards. New legislation before the provincial government is now reiterating the possibility of severe consequences for inappropriate development or failure to flood proof, although generally it is believed that such severe action would not be taken by the provincial government.

The third provision, i.e. to encourage local authorities to zone on the basis of risk, has been only partly successful. It has left the decision on whether or not to include appropriate building elevations in municipal zoning by-laws to the discretion of municipal governments. Some municipalities have used Designated Flood Area maps regularly and effectively in approving development, and have included floodproofing criteria in their zoning by-laws. Others have not used the information effectively, and in some instances, suffered the negative consequences of this failure in the 1997 flood. There are nine municipalities in the Designated Flood Area in Manitoba so leaving such issues to the discretion of municipal governments has, not surprisingly, led to much inconsistency in land use regulation.

An umbrella agreement within the 1975 Flood Damage Reduction Program is in effect until March 1999. It allows for continuing federal assistance for flood protection works in the Red River Basin. This will contribute to new construction works and reparations to existing works in communities affected by the 1997 flood.

3.2 Flood Management in Manitoba - Overview of Responsibilities

Because a detailed overview of all authorities involved in flood fighting and recovery is beyond the scope of this paper, only the key ones will be briefly presented. Only their mandate with regard to floods will be mentioned.

Manitoba Natural Resources Department (DNR) - Water Resources Branch is primarily responsible for flood planning and management. For floods in the Red River Basin the DNR's Central Region carries out the delivery of flood related services. Water Resources Branch administers nine Acts: The Water Resources Administration Act, The Dyking Authority Act, The Water Commission Act, The Water Rights Act, The Ground Water and Water Well Act, The Rivers and Streams Act, The Water Power Act, The Water Supply Commissioners Act, and The Lake of the Woods Control Board Act. They are responsible for flood management activities such as forecasting, operation of flood control works, monitoring of flows/levels, and dissemination of information as necessary. They also interface with the City of Winnipeg, municipal governments and other government departments.

Manitoba Natural Resources Department (DNR) – Regional Operations is responsible for field activities, enforcement of legislation, emergency response to floods, and delivery of services at the community level.

DNR-Regional Engineering Staff maintain and operate flood protection systems in eight rural communities, the Red River Floodway, and Portage Diversion.

DNR-Operations Division provides security to diked communities, and search and rescue during large floods

Manitoba Emergency Measures Organization (EMO), part of Manitoba Government Services, works with and coordinates federal government's involvement contribution (including financial) during natural disasters such as floods. As the civil defense agency, they help in coordination of emergency response per The Emergency Preparedness Act.

EMO also coordinates damage claim assessment and communicates with federal government about their share of recovery costs according to the federal Disaster Financial Assistance Arrangements (DFAA) and the Canada –Manitoba Agreement on Red River Flood Disaster Assistance (1997).

4. STRUCTURAL MEASURES

Structural measures are flood damage reduction measures that attempt to keep flood waters away from people and property. The most common are reservoirs, levees, dams, dikes and control systems such as the Winnipeg Floodway. They can also include drainage systems and river channel improvements which alter how water flows.

Without doubt it was the 1950 flood, a huge natural disaster, that clearly revealed the vulnerability of settlements along the floodplain in southeastern Manitoba, and the high costs associated with flood damages. For instance, in 1950, approximately 640 square miles of cropland along the Red River were submerged; all towns within the flooded area were evacuated and 100,000 people evacuated from Winnipeg alone as 10,500 homes in the city flooded. Close to $30 million was paid in damages (United States Geological Survey, 1952 in Rannie, 1980). See Red River Basin map of areas flooded in 1950 in Appendix A. Total damage estimates ranged up to as much as $114 million. This was enough to prompt all levels of government to search for ways to mitigate the flood hazard.

4.1 Evolution of a Large-scale Flood Control System in the Red River Basin

The first large-scale water control structure in Southern Manitoba was intended as a temporary ameliorative measure: it was a boulevard diking system constructed after the 1950 flood in the greater Winnipeg area. Although intended as only *temporary*, it was followed by six flood-free years. This created a false sense of security and no permanent flood protection plans were made until a narrowly averted flood threat in 1956 served as impetus for a more comprehensive structural plan.

In response to the 1956 threat, the Provincial Government took the first steps in development of a more far- reaching long- term flood damage reduction plan for Manitoba. They established a Royal Commission to prepare a benefit–cost analysis for a range of flood protection schemes. They considered traditional structural approaches such as channel improvements, increased diking systems, detention reservoirs, and also a more radical response, the diversion of floodwaters to protect vulnerable areas. The comprehensive flood control system (Figure 3) which was finally adopted included an extensive plan to divert water around the city of Winnipeg. It was constructed from 1962-72, with federal and provincial governments sharing the costs, a 60%-40% split respectively.

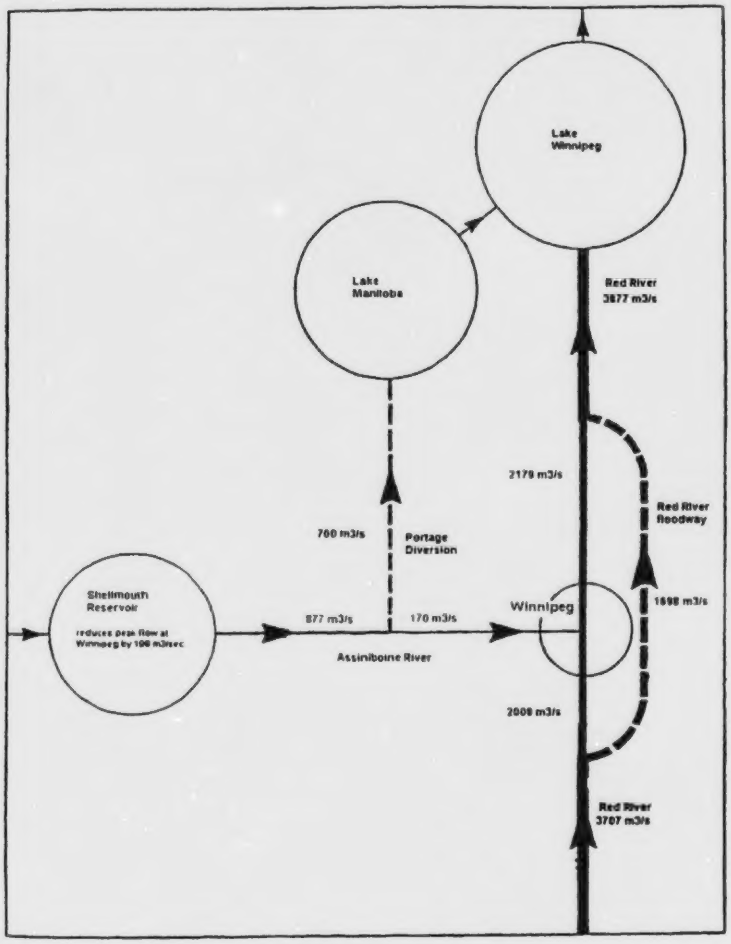


Figure 3 - Schematic drawing of flood control system (Source: Mudry et al, 1981)

The 1958 Royal Commission's recommendation for extensive structural works was largely based on benefit-cost ratios they determined for three major components of the plan. These three main components were the Red River Floodway, The Portage Diversion and the Shellmouth Dam, at costs of $62.7 million, $20.5 million, and $10.8 million respectively. A recommendation to construct ring dikes for parts of Winnipeg and vulnerable non-urban communities was also included, at costs of $4.6 and $4.7 million respectively. Total cost of the flood control system was $103.3 million. See Table 2 for the benefit –cost ratios calculated by the Royal Commission for the major components.

Table 2 – Original Benefit-Cost Analysis Summary (Annual Method)

(Source: Mudry et al, 1981)

	Construction period assumed (years)	Estimated capital cost	Interest during construction period	Total estimated capital cost	Annual amortized cost at 4%	Annual O & M cost	Total annual cost	Average annual benefit	Benefit - cost ratio
Red River Floodway 1,700 m^3/s		57,361	5,736.1	63,097.1	2,937.2	224.5	3,161.7	9,127.2	2.89
Portage Diversion 700 m^3/s	2.5	8,672	433.6	9,105.6	423.8	82.4	506.2	4,586.6	9.06
Shellmouth Reservoir	2.5	6,450	322.5	6,772.5	315.3	18.6	333.9	2,062.4	6.18
Above three projects combined		72,483	6,492.2	78,975.2	3,676.3	325.5	4,001.8	10,921.1	2.73

(1) All financial figures in $000 (1957 dollars)

(2) Source: "Report of the Royal Commission on Flood Cost Benefit", 1958, Tables II.2, II.4 and II.1

(3) Benefits are not additive due to duplication of protection at lower flood levels

(4) A 50-year period of analysis was used for the amortization

(5) The incremental benefit of the Shellmouth Reservoir considered as an "add-on" to the Red River Floodway and Portage Diversion are $470.3 thousand, for an incremental benefit-cost ratio of 1.41

Political opposition because of the costs caused some delays; however, all three components were completed by 1973. The need for a comprehensive system was verified by the number of flooding events throughout the 1960s and 1970s. Floods occurred in 1966, 1969,1974, and 1979, clearly showing an escalating frequency. See Figure 4 for a depiction of the revised frequency curves calculated in 1976 as compared to those used in 1958, for three different locations. After the 1996 and 1997 floods, frequency curves need again to be formally revised, but have not been done as yet. This would allow for a better analysis of how efficient the flood control system has been.

W.F. Rannie, in 1979, calculated that a new benefit-cost ratio for the flood control system protecting Winnipeg would likely have been 20% higher than that of the Royal Commission based on the increased frequency of flooding. Overall, these altered frequency curves would increase the long-term average annual damages calculation. This would, in turn, increase benefit-cost ratios of the components of the flood control system as compared to those ratios used by the Royal Commission (Rannie, 1980). This would mean that the flood system actually provides more protection than anticipated, as average annual damages along the Red and Assiniboine Rivers will have risen 20-25% above the Royal Commission's annual damage calculation (circa $17 million) because of increased frequency of high discharges.

It is also likely that the Royal Commissions calculations of flood costs were very conservative because they may have underestimated the cost of flood fighting in future decades, and probably did not adequately predict the significant economic growth within the area protected by the control system. Some of this growth has likely been a result of an increased perception of safety within the protection of the Floodway (called "project-induced development"). In fact, the creation of a false sense of security and therefore uninhibited growth is a significant weakness of structural flood mitigation strategies.

The use of a major structural system to reduce flood damage to Winnipeg was essential. See Figure 3 illustrating the main components of the system which protects Winnipeg. When the devastating 1950 flood was quickly followed by successive smaller floods, it was evident that only structural measures could provide a significant reduction in flood damages. The land was already in use; the benefits of more appropriate land use would be evident only over a period of time.

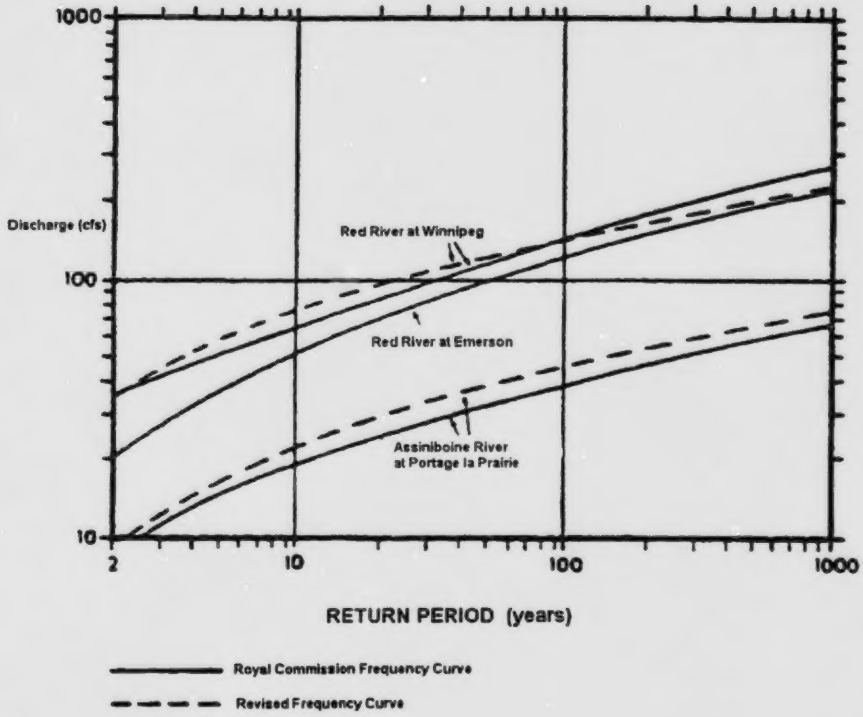


Figure 4 – Comparison of Flood Frequency Curves Used by the Royal Commission with those Revised to 1976 (Source: W.F. Rannie, 1980)

4.1.1. Post-Project Evaluations

There has been astonishingly little done in the way of *formal* analysis of the success of flood damage mitigation measures along the Red River Basin in Manitoba. The only available post-audit was done in 1981 by the International Commission on Irrigation and Drainage. This was done exclusively on the flood control system that protects Winnipeg. A summary of their benefit-cost analysis is found in Table 3.

Table 3 – Benefit-cost analysis summary using the actual costs, updated benefits estimates and the actual construction period (Source: Mudry et al., 1981)

Combined Projects Scenario 2	Years	0	1	2	3 to 5
	Benefits	Nil	Nil	Nil	Nil
	Costs	2.5	10.0	10.3	13.8
	Net Benefits	-2.5	-10.0	-10.3	-13.8
	Years	6	7 & 8	9 & 10	11 to 60
	Benefits	Nil	11.0 & 11.2	13.0 & 13.2	14.1 to 30.4
	Costs	6.5	4.0	1.4	0.3
	Net Benefits	-6.5	7.0 & 7.2	11.6 & 11.8	13.7 to 30.1

		Present value at			
	Discount Rate	4%	5%	10%	13%
	Benefits	306.7	236.4	84.4	53.3
	Costs	75.1	71.5	58.6	53.3
	Net Benefits	231.6	164.9	26.1	0.2
	Benefit-cost ratio	4.09	3.31	1.45	1.00
	Internal rate of return	13.0%			

(1) All financial figures in millions of 1957 dollars

(2) Computations may not appear exact due to rounding error.

(3) Scenario 2 – See Table IV.

(4) Sources :

- "Flood Control Red River Floodway, City of Winnipeg Dykes, Portage Diversion, Shellmouth Reservoir, Fairford River, Assiniboine River Dykes" Province of Manitoba, Department of Mines, Resources and Environmental Management, 1974.
- "The Red River Floodway", Province of Manitoba, The Highways Department.

They concluded, in 1981, that the actual benefits accrued then to date were well in excess of actual costs. They estimated gross value of damage reduction in 1979 to be just over $1 billion (1979 dollars; 10% discount rate). See Table 3 for the benefit-cost summary. Their final determination was a 4.09 cost-benefit ratio, very similar to the 4.1 ratio of the Royal Commission (when the Commission tried to take growth into account). This analysis did not include a detailed look at development and property values in Winnipeg as it was beyond the scope of the project.

There is little credible analysis on the efficiency of the flood control system after the 1979 flood. There is a general belief that it has been enormously successful. New detailed analysis on how successful the flood control system has been will hopefully be forthcoming following the 1996 and 1997 floods.

There is clearly a need to look at community ring diking and its success as a mitigation measure. Many ring dikes were enhanced or constructed through the 1980s and 1990s and have now been tested by recent events. Sources in government expressed their belief that a comprehensive look at the issue would be useful. Right now the institutional focus is largely on assessing what occurred in the 1997 flood, determining damages, and planning new structural mitigation strategies.

4.2 Structural Measures in the Red River Basin

4.2.1. The Red River Floodway

The Floodway was the most costly part of the Red River flood control system (Table 4). It offers significant protection to Winnipeg during flood conditions. It permits the Red River to flow normally through Winnipeg when discharge is normal, but if it exceeds 30,000 cfs the water flow is divided between the Red River and an excavated earth channel (i.e. Floodway). The Floodway was designed to carry water up to a capacity of 60,000 cfs; it diverts the water in a 29.4 mile loop around the city beginning just south of the city (St. Norbert) and ending just north of Winnipeg (Lockport). Average depth of the channel is 30 feet. Bottom width ranges from 380 feet to 540 feet; top width ranges from 700 feet to 1000 feet.

Table 4 – Main characteristics of the Red River Floodway

Measure	• excavated channel about 30 miles long
Implementation	• on advisement of 1958 Royal Commission , based on benefit-cost analysis • completed in 1968, at cost of $62.7 million
Responsibility	• operation and maintenance done by Manitoba Natural Resources- Water Resources Branch
Goal	• to divert flood waters in excess of 30,000 cfs around the city of Winnipeg from south to north
Efficiency	• highly successful within technological limitations
Issues	• inappropriate development in highly vulnerable areas due to exaggerated sense of security within the protected area • institutionalization of flood damage reduction (perception that flood damage reduction is a government function and not a public issue) • if flood waters exceed channel capacity, damages could be extremely high • capacity insufficient to handle flood equal to that of greatest flood on record (i.e.1826) • operation is poorly understood by the public, prompting criticism • allegations that operation caused excessive flooding south of structure • currently the Floodway is being refurbished , a three year project costing over $3 million • provincial government claims Floodway has saved over $4.5 billion in potential damages to Winnipeg

In addition to the channel itself, the Floodway consists of what is called the **West Dike**; its function is to keep flood waters on the west side of the Red River from entering Winnipeg. It starts on the west bank of the Red River and runs west and south. Originally it was 20 miles long, but due to the flood of 1997 there was an extension of another twenty-one miles to prevent Red River water flowing around the western edge of the original dike and into Winnipeg. This was the first flood since the Floodway was constructed that the provincial government acknowledged that it may not be sufficient to protect Winnipeg: there was fear of overland flooding into Winnipeg if the La Salle River system west of Winnipeg received too much water from west of the Red River. The solution was the addition to the West Dike system known as the Brunkild or "Z" dike. Remarkably, it was erected in 72 hours, contained 900,000 cubic yards of clay and other materials, and averaged 9 feet in height over 24 km. Because of its hasty construction, it later had to be dismantled but is being permanently relocated to run along PTH 305 (provincial trunk highway) as part of the West Dike system.

The third component of the Floodway is the **Inlet Control Structure** south of St. Norbert which regulates water levels on the Red River at the entrance to the floodway. Two gates (112.5 feet long; 34.8 feet high) are located here, and are raised to regulate upstream water levels.

The operation of the floodway is subject to specific rules which regulate water levels and contain contingencies to handle excessive ice, erosion damage, and various flow scenarios south of the city. The major rules that apply (assuming ice jams are not a problem) are presented in Table 5.

Table 5 – Winnipeg Floodway operating rules

For natural flows on the Red River north of the Assiniboine River up to 169,000 cfs	• maintain natural water levels at the Floodway Inlet
For natural flows from 169,000cfs to 189,000 cfs	• maintain 25.5 ft. at James Avenue
For natural flows from 189,000 cfs to 199,000 cfs	• at 190,000 cfs raise City's primary dike levels to 30.5 ft. • allow water to reach 29.5 ft. at James Avenue, with water elevation at the Inlet being 775.8 ft.
For natural flows from 199,000 cfs to 217,000 cfs	• maintain 29.5 ft. at James Avenue • raise water levels at Inlet to a maximum of 778.0 ft.
For flows above 217,000 cfs	• water levels at Inlet not be exceed 778.0 ft.

These rules are occasionally revised as required. This occurred during the 1997 flood where concerns arose about the following: a) consequences of heavy wind and resultant waves; b) possible survey errors and uncertainties; c) likelihood of significant amounts of sewer backup with James Avenue levels of 25.5 ft. and; d) realization that with James Avenue levels of 25.5 ft. secondary dikes in some parts of the city would be overtopped. Consequently the operating rule defining the maximum acceptable water level at James Avenue was altered to 24.5 ft. from 25.5 ft. (Manitoba Natural Resources Submission to the Manitoba Water Commission, 1997). This operating decision has been subject to criticism, particularly by residents south of the floodway, who feel that they may have been subjected to a *significant and damaging* increase in water level due to the reduced intake through the city. This dispute will likely continue for some time into the future.

4.2.2. Portage Diversion

The Portage diversion consists of an excavated earth channel two miles west of the city of Portage la Prairie (Table 6). It diverts water from the Assiniboine River to Lake Manitoba, which is 18 miles to the north. While flow capacity during most of the length of the channel is 25,000 cfs, it is reduced to 15,000 in the last 3-4 miles. Excess water spills harmlessly into a marsh. The water flowing into the channel is controlled by a diversion dam upstream on the Assiniboine River which has four lift gates 40 ft. wide and 14.5 ft. high. As the gates are raised, water flows increasingly down the diversion. Just east of the entrance of the diversion channel there is a spillway dam on the Assiniboine River which creates a reservoir of some 1600 acres; the reservoir water elevations are controlled. The control structure itself consists of two gates (13 ft. high by 75 ft. wide.). During high water flow (e.g., spring) the gates are raised and lowered to control water flowing into the Assiniboine River. During most summers, left in a fully raised position, no water usually flows over them. Summer-time release of water can occur through a gated pipe in the dam even when the gates are in the fully raised position.

Like the Floodway, there are operating rules and objectives for the Portage Diversion. The operating *rule* is to maintain flow on the diversion channel at or below 25,000 cfs. The main *objective* is to control waters to keep levels in Winnipeg below 17 or 18 ft. (James Avenue). Ice and ice jams are closely monitored and adjustments made to reduce jams. Adjustments are also made to minimize damage to agricultural land along the river, and prevent bank and dike slumping when possible.

Table 6 – Main characteristics of the Portage Diversion

Measure	• consists of a diked earth channel, a diversion dam and spillway dam • channel is two miles west of city of Portage la Prairie • diverts water from Assiniboine River to Lake Manitoba 18 miles to the north
Implementation	• recommended by Royal Commission (1958) • completed in 1970 • cost $20.5 million
Responsibility	• Water Resources Branch
Goals	• To keep water levels in Winnipeg at acceptable level---below 17 ft. or 18 ft. at James Avenue • Protect agricultural land and communities downstream from Portage la Prairie
Efficiency	• highly efficient, subject to ◆ problems with ice jams which can significantly reduce diversion channels capacity ◆ technological limitations
Issues	• Diversion is most essential when the Red River and the Assiniboine both crest at or close to the same time; Winnipeg floodway would otherwise be heavily taxed • Reduces flood damages along lower Assiniboine River, much of which is agricultural land • May have contributed to false sense of security along lower Assiniboine River

4.2.3. Shellmouth Reservoir

This reservoir is located on the Assiniboine River near Russell Manitoba (Table 7). There is an earth-fill dam and associated 35 mile long reservoir. The reservoir has a maximum depth of 40 ft; maximum water storage is 387,000 acre feet (477,357,534 m^3). Discharge over the overflow spillway occurs at 1408.5 ft.; there is also a discharge conduit through the dam to permit water discharge at other times.

Similar to the other major structures of the Red River flood control system, rules apply to the Shellmouth Reservoir. In spring, the main goal is to control the reservoir outflows to minimize downstream flooding; care is taken to also minimize *local* flooding and facilitate local land drainage. In fact over the fall and winter, the reservoir is gradually lowered in anticipation of spring waters. The degree to which it is lowered is dependent on probabilistic forecasts although at one time an operating rule set a target winter level of 1391.0 ft. Now it is adjusted to both accommodate anticipated spring flows and ensure enough water storage for use as local water supply and to meet recreational needs over the summer.

Table 7 – Main characteristics of the Shellmouth Reservoir

Measure	• consists of earthfill dam, overflow spillway, and reservoir • Located on Assiniboine River near Russell, Manitoba
Implementation	• Recommended by Royal Commission (1958) • Completed in 1972 • Cost $10.8 million
Responsibility	• Water Resources Branch
Goals	• provide water storage and control reservoir outflows to minimize downstream flooding in spring or during summer rainfall flood conditions • ensure adequate water supply in summer

In summer, the target level in the reservoir is 1402.5 ft. Outflows, normally kept to a value equal to the river flow if no dam existed, will be increased if rainfall floods occur which raise the reservoir levels above 1405 ft. This is done to reduce flooding of recreation facilities and prevent the spillway from being overtopped; otherwise localized flooding may occur. Under summer non-flood conditions, reservoir releases are based on water allocation needs downstream and adjusted as necessary to attempt to meet a minimum target instream flow of 25 cfs right below the dam and 200 cfs at Headingly, Manitoba. Overall, there are seasonal operation strategies which are altered as necessary depending on hydrologic conditions and forecasts; updates on conditions are done monthly from November to March, weekly or daily during spring runoff, and after major rains in summer.

4.2.4. Diking within Winnipeg

A permanent diking system in Winnipeg (Table 8) was begun immediately following the devastating 1950 flood, and is a significant feature of the overall flood damage reduction system in Manitoba. Over sixty-five miles of boulevard dikes with 22 pumping stations were initially constructed to protect against James Avenue water level heights of 26.5 feet, four feet below the 1950 flood level; emergency temporary dikes would also be needed for a flood of that magnitude. These permanent dikes were further enhanced as successive floods revealed their inadequacy. The recent 1997 flood's high water level happily did not actually exceed the levels of the primary diking system of the city.

Table 8 – Main characteristics of the Winnipeg diking system

Measure	earth dikes and pumping stations
Implementation	recommendation of Royal Commission (1958)
	initially implemented by the Greater Winnipeg Diking Board 1950-52 with involvement of three levels of government, later enhanced
	initial cost (1950-51) $6 million, cost of enhancements in subsequent years undetermined
Responsibility	Water Resources Branch (per the Diking Authority Act)
Goals	protection of Winnipeg property from flood waters
	pumping stations operate to lift water and sewage waste over boulevard dikes and prevent sewage back-up
Efficiency	adequate only to a limited water level
	easily breached under bad weather conditions or in very long duration floods
	must be properly maintained
Issues	permanent dikes are insufficient for highest water levels on record
	some Winnipeg riverbank properties could not be protected by dikes due to proximity to river
	some residents have removed the dikes on their property for aesthetic reasons, placing entire community at risk

4.2.5. Ring Dikes

Ring dikes around major communities south of Winnipeg (Table 9) are another structural measure undertaken to reduce flood damages in the Canadian portion of the Red River Valley. Initial dikes around upper valley communities were constructed on the recommendation of the 1958 Royal Commission; the Commission saw this as the most cost-effective protection for the upper valley.

Table 9 – Main characteristics of ring dikes

Measure	• ring dikes around select communities (earth)
Implementation	• recommended by Royal Commission (1958)
	• cost – benefit analysis conducted prior to construction on 8 communities
	• first ring dikes completed in 1972, cost $2.7 million
	• from 1982-1991 new ring dikes and old dike enhancements cost $4 million; this figure is $6.9 million if *total* expenditures on the diking systems are included (such as pumping stations, communications equipment…)
	• new ring dikes anticipated following the 1997 flood
Responsibility	• Water Resources Branch – regional engineering staff (for maintenance and operation)
Efficiency	• adequate, subject to water level heights, weather conditions and maintenance/monitoring of dike
Issues	• dikes must be maintained, monitored and often enhanced during flood conditions
	• dike openings such as roads and railways must be closed with earth during floods
	• adequate pumping facilities must be in place
	• municipal cooperation required for construction and maintenance of dikes

The first ring dikes cost $2.7 million and were built in the early 1970s through a federal-provincial agreement. The towns diked were Dominion City, St. Jean Baptiste, Morris, Rosenort, and St. Adolphe. The first dikes were completed in 1972.

Unfortunately the floods over the next decade showed that many ring dikes were simply inadequate to protect the valley communities. In 1976, the government of Canada (under the Canada Water Act) and Manitoba signed "A General Agreement Respecting Flood Damage Reduction"; one of the agreement's objectives was to reduce future flood damage by constructing structural works (dikes and diversions) for communities where benefits of the works were seen to exceed costs of the works.

Economic studies did confirm the benefits (over costs) to upgrading existing ring dikes and building new ones. Consequently provincial and federal governments signed "An Agreement Respecting the Upgrading of Ring Dikes in Certain Communities in the Red River Valley" and began more new dike construction and improvements to some of the already existing ones to bring them to the 100 year flood level. Costs of the agreement were about $5.4 million. Later (1985) the Agreement was amended to include more work in Ste. Rose du Lac and Souris. A further amendment in 1989 added to the amount of funds available by $800,000 (for a total of $6.9 million) and a 2-year extension which were necessary to complete various tasks. In addition to upgrading and constructing new dikes, funds were used in the targeted communities to provide, as required, pumping stations, improved drainage systems, emergency communications towers, and other equipment.

5. NON-STRUCTURAL MEASURES

Nonstructural flood damage reduction measures are essentially those measures which are not of a structural nature, i.e. do not involve construction. Examples of nonstructural measures can include flood insurance, development policy, zoning laws, and floodplain regulations, building codes, flood-proofing activities, tax incentives, emergency preparedness, flood forecasting and post-flood recovery (Krenz and Leitch, 1993). In the Red River Basin, structural measures such as the Floodway, the diversions, and diking systems have been the primary focus of flood damage reduction activity. These activities alone are not adequate in the long-term because of their high costs, high maintenance, probability of partial or complete failure (under some conditions), and the enormous repercussions from failure.

They also cannot resolve all problems facing areas vulnerable to flooding, particularly in the not uncommon scenario where technology fails to accurately predict nature. Flood prevention and damage reduction is a highly complex problem with not only a technical or engineering dimension, but a multifaceted human dimension as well. Many of the non-structural measures rely on human values, cognition and behavior – both the public's and government's alike.

5.1 Flood Fighting

Flood fighting and emergency response activities are vital to reducing flood damages. A broad overview of flood fighting issues pertinent in the Red River Valley will be provided (Table 10). The recent 1997 flood has prompted a re-evaluation of flood fighting strategies, and recommendations for improvement.

Table 10 – Main characteristics of flood fighting non-structural measure

Measure	• Flood fighting includes those activities done prior to or during a flood with the intent of reducing damages from the flood
Responsibility	• Water Resources Branch of the Department of Natural Resources • EMO (Manitoba Emergency Measures Organization) • three levels of government • individual property owners
Issues	• need for *ongoing* emergency preparedness and planning, to ensure adequate needs assessment and timely access to human and other resources • proactive and long-term planning required versus reactive • optimal use of forecasts to determine flood fighting strategies, and provide sufficient warning to at-risk areas • improve flood response in some rural municipalities • improve public awareness of provincial government's flood fighting activities, including more specific information on the operation of the Floodway gates

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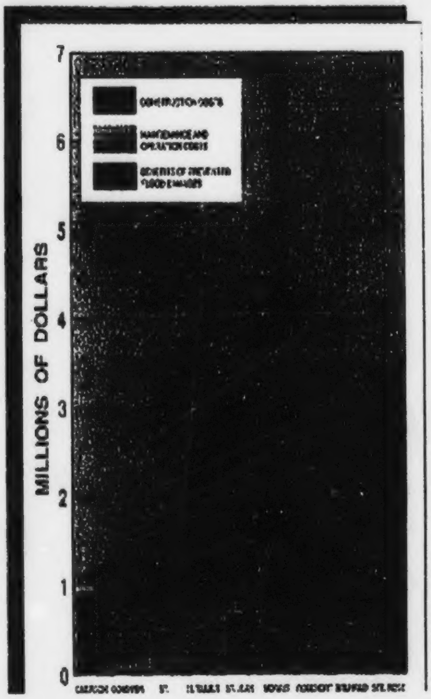


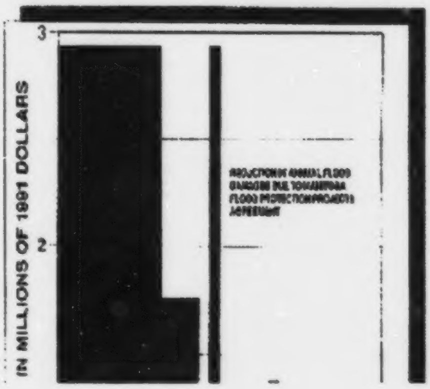
The benefits from prevented flood damages has averaged about 2 million dollars per community under the agreement.

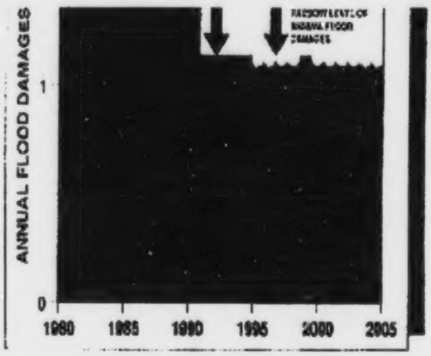
Figure 5 – Benefits from prevented flood damages
(Source: Government of Canada, 1991)

All expenditures in the Agreement were cost-shared by federal and provincial governments – a 55%– 45% split. When the work was completed in 1991, the report detailing the Agreement's completed tasks recommended further structural flood damage reduction works deemed necessary to prevent sizeable damages in future (Figures 5 and 6). The intent was to provide affected communities with both sustainability and increased economic development potential that had not been fully available to them in the past.

Spring of 1997 brought new stress to the Red River Valley. Flood projections that year revealed that most of the ring-diked communities south of Winnipeg were insufficiently diked for the anticipated inundation. Many ring dikes had to be raised; these communities were spared. One community, Ste. Agathe, which had no ring dike, flooded unexpectedly from overland flows from the west; the River lies to the east. A bedroom community of Winnipeg – Grande Pointe also flooded unexpectedly and severely. The cause of this unexpected flooding is under investigation. These two examples point to difficulties in forecasting such complex flood events and the previously mentioned challenges of predicting the movement of overland flows.

New community floodproofing projects are planned in communities hit hard by the 1997 flood; the federal and provincial governments together have committed $12 million to date for flood protection for both communities and individuals, with more monies anticipated. Natural Resources has raised the existing ring dikes in eight valley communities to two feet above 1997 flood levels. Engineering feasibility studies for diking have been completed for twenty communities, and five communities have moved into the construction stage. Municipal governments are expected to financially contribute once the plans are formalized for municipal floodproofing.





The construction of flood protection works for communities still susceptible to flooding would prevent millions of dollars in future flood damages.

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4.2.6 Individual Rural Homesteads

Under an overview of structural measures adopted in the Red River Basin in Manitoba, mention should also be made of the structural measures employed by individual rural home owners and farms not protected by ring diking. Recognition of their vulnerability was evident in damages during the 1966 flood and particularly in the 1979 flood. Joint federal-provincial programs gave incentives to rural residents to raise homes and buildings in both 1966 and 1979, and build dikes around structures. Again the hundred-year flood level was the standard used in building. There was now clear evidence of an organized, institutionalized approach to flood damage reduction through structural measures. Also in 1979, a special federal–provincial flood relocation program included a nonstructural measure, i.e., purchase of high-risk residences, to other flood damage reduction strategies (IJC, 1997).

Owners of rural properties not protected by community dikes in the 1997 flood are eligible for the current Flood Proofing Program discussed under Non-structural Measures of Flood Damage Reduction.

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4.3 Final Comments on Structural Measures in the Red River Basin

Without doubt, the floodway has proved its value to the City of Winnipeg; at no time was this better illustrated than in the recent 1997 flood. Structural measures certainly can reduce or eliminate flood damage within the area they are designed to protect. However, the experience of Manitobans has a negative side according to some experts' analysis. Concern has arisen as to the implications of a "two-tier system of protection" (Bumsted, 1997, pg. 137) such as exists in the Red River Valley, i.e., those protected by the floodway versus those not. Questions naturally arise such as: What can those who are not protected reasonably expect in terms of assistance pre and post flood? Should protected residents shoulder costs of rehabilitation or compensation for the non-protected? Should restoration/compensation be offered to those

whose structures do not comply with floodproofing standards?

Controversies also abound about whether or not the operation of the Floodway (and the artificial diversions of water resulting from structural measures) have increased hardship to some communities by diverting water *towards* them. These accusations stem back to the 1974 flood after which public hearings and consultations *confirmed* improper floodgate control had produced an upstream level 2.1 feet higher than normal. Throughout this time, engineers had insisted that public perceptions of raised levels was purely "psychological". This was a pivotal event in government-public relations in some respects, because it confirmed to some extent that "experts" and government might be wrong in their statements (at best) or dishonest (at worst).

The resultant distrust of experts and bureaucrats continued through the next two decades and is exemplified in the demands for public inquiries by upper Red River Valley residents following the recent 1997 flood. The public inquiries are to address questions about government floodgate operations. The decision to alter one operating rule of floodway operation by reducing the water height maximum permitted at James Avenue at Winnipeg (see Floodway section) is being questioned. The inquiry is to examine the consequences (if any) of floodgate operation, authorized road cuts, and other flood control activities on water levels in the upper valley. This issue of responsibility for water levels and subsequent flood damages is crucially tied to financial liability; residents feel if government actions contributed to the problem, they should fully compensate for losses incurred by residents.

False sense of security and the resultant complacency of people protected by the major structural flood damage reduction measures in Manitoba are a problem. Complacency has encouraged the "project-induced development" in the floodplain previously mentioned, so that with each successive flood the *potential* damage if structural measures fail is escalating. It is important to also note that the 1826 flood, the most severe on record, inundated all of metropolitan Winnipeg, except for the western portion. Thus today much of the city is at risk, a risk heightened by the fact that the existing floodway may not contain waters of the 1826 flood's magnitude. This exemplifies the need for a long-term approach to flood protection, and implementation of other strategies (such as non-structural ones) to complement structural ones if flood damage reduction is a primary goal.

Finally, not enough post-construction analysis has been done to examine structural flood damage mitigation measures, particularly in rural communities. Structural measures in the Red River Basin are usually built reactively in response to recent damages sustained; a continuing saga of structural measures may protect pockets of land, but the question arises of where will the water then go? For this reason, it is necessary to look also to non-structural options

Issues	- establish nature of government liability, if any, for damages resulting from inaccurate predictions of water levels - improve individual property owners' and communities' emergency response

5.1.1. Evolution of Flood Fighting Practice and Policy (1950 – 1998)

Probably one of the earliest non-structural measures to help mitigate flood damage in the Red River Valley took the form of a 1950 post-flood recovery policy in which the federal government provided 75% of the major costs of what they deemed "rehabilitation" (Bumsted, 1997). This policy emerged because this flood had been officially declared a "national emergency". This "rehabilitation" approach was laced with difficulties both philosophical (i.e., what was rehabilitation?) and practical (who paid for what? who was entitled?). Prior to the 1950 flood private funds and charities had provided the first organized flood relief, and private agencies--not government--had coordinated flood fighting and assistance.

From the 1950 flood onwards, there would be increased demand for compensation for those not protected by structural flood measures (earth and sandbag dikes in 1950 terms; in later years the more elaborate flood control measures) and by those who perceived that they suffered damages because of the control measures.

Government was now increasingly in the leadership role in both flood preparation and flood damage reduction. The first disaster-fighting policy began to establish the provincial government as primarily responsible for local disaster relief, with federal government offering some limited cost sharing. The need for preparation for disaster rather than denial of the risk was becoming evident.

While engineers began the first in-depth analysis of proposed structural measures to protect Winnipeg after the 1950 flood, the city began the first formal organized flood-fighting strategy in advance of an actual flood occurrence. This strategy was essentially to protect waterfront property only; called the "Line of Defense"; it relied on the standard structural measures of the day—boulevard diking and stockpiled sand and clay for anticipated use. Yet it was preventive and proactive in nature, unlike most previous strategies.

The emergency preparedness aspect of flood management was more formalized yet with the creation in 1957 of the Emergency Measures Organization (EMO). They became involved more specifically in flood management in the Manitoba flood of 1966 as Manitoba's disaster response was more institutionalized. The Manitoba EMO took over response operations in successive floods and could, through newly developed policy (e.g. The Flood Operation Order, 1966) coordinate involvement of other provincial and federal departments, RCMP, the military, Red Cross and others.

Flood fighting in the 1969 flood was hampered by the nature of the relationship between provincial and municipal governments. Municipal governments were criticized for delaying their disaster preparations because they were responsible for flood costs until a provincial emergency was declared. This unfortunately resulted in excessive damages in some local communities, such as Carman, Manitoba.

The vulnerability of those inside versus outside the Floodway began to cause increasing questions and feelings of inequity through the 1970s. Floods of serious magnitude were occurring with more frequency over the first decade following the completion of the complex control system to protect Winnipeg; it is not surprising that upper valley residents began to be suspicious that the Floodway, particularly, may have been somehow diverting water flow in such a way as to increase their risk of flood damages. EMO were now beginning to spend a significant amount of time responding to claims that losses and damages south of the city were in fact man-made rather than natural disasters.

5.1.2. The 1997 Flood

Criticisms by upper valley residents continue to plague Water Resources and EMO officials even as we approach the second millennium. Evidence of this lies in the 1997 flood in which the public demanded an investigation into the activities of authorities (such as operating the Floodway, road cuts, etc.) to see if these flood-fighting activities (many done to save Winnipeg) contributed to other properties flooding.

Fighting the flood of 1997 revealed to Red River Valley residents the need for more than just an institutional response to a flood of large magnitude. Fighting this flood (and the recovery process) was a huge organizational task. For example, with the leadership of the Water Resources Branch and EMO, flood fighting included flood monitoring and forecasting activities, coordination and communication with government and non-government agencies, volunteer coordination, organization of victims' services, implementation of evacuation procedures, transportation routing, public communications, security and search and rescue activities. Enormous effort was expended by the provincial government to provide resources and assistance in the construction of individual and community dikes, and the astonishing 24 km Brunkild Dike. The enormity of the task of flood preparation and fighting in 1997, and the huge damages and life disruption, exposed the need for communities and individuals to assume more responsibility in planning and mobilizing for future floods, and not rely so fully on institutional supports. In the case of large magnitude floods, this change in attitude and behavior is essential to flood damage reduction.

Flood fighting activities by municipal governments have also come under some criticism in the 1997 flood, criticisms not only that they were ill-prepared but that they delayed their disaster preparations, fearful of the costs. It is interesting to note that these issues are the same as those raised in 1969, and apparently remain unaddressed.

5.2 Flood Forecasting and Warning

The two crucial issues in how forecasting contributes to flood damage reduction are lead time and how the residents who receive the warning choose to respond to the information. The degree of warning particularly affects the magnitude of content damages because moveable items can be removed from the path of water if time is sufficient (McBean *et al.*, Adjustment Factors for Flood Damage Curves. 1988).

Table 11 – Main characteristics of flood forecasting and warning measure

Measure	River streamflow forecasting involves complex analysis of the many variables which influence river levels, to ultimately best anticipate levels using probability calculations.
Responsibility	Water Resources Branch – River Forecast Centre
Issues	enhanced use of modeling techniques needed improved communication of risk to the public improved prediction of overland flows

It was not until after the devastating 1950 flood, that river forecasting became more formalized. By 1957, when the Provincial Water Resources Branch was consolidated to deal with all aspects of water resources and management, "water forecasts" effectively began. Improvements to forecasting capability were seen in the 1970s, and the Manitoba River Forecast Centre was established.

In the 1980s, with impetus from the Canada-Manitoba Flood Damage Agreement on Flood Forecasting, there was a detailed seven-year stream-flow simulation study, and the testing of several forecasting models. Ongoing improvements to forecasting methodologies have also resulted from enhancements to computer technology.

5.2.1. The 1997 Flood - Current Forecasting Activities

It is well known that the biggest flood risk in Manitoba is spring flooding (see section 2.2 of this report). The River Forecast Centre of the Water Resources Branch in Winnipeg is responsible for streamflow forecasting in the Red River Basin. Using and analyzing data from a variety of sources, two types of runoff forecasts are made in the spring, one preliminary and one operational. The former is made well in advance of spring runoff to help predict peak flows and water levels under various scenarios. Operational forecasts are made once runoff has begun, and predict daily and peak river levels and dates. Manitoba relies heavily on the United States of America's National Weather Service's predictions for the Red River (at Pembina), largely because 80% of the total runoff on the Red River comes from the United States portion of the Basin. Overall, the analysis of multiple sources of data and multiple variables (soil moisture levels, precipitation, snow pack, tributary discharge, etc.) makes forecasting a very demanding job (Appendix A-1, 2).

The main cause of the excessive flooding in 1997 was an extreme snowpack (98 percentile). There was also high topsoil moisture due to fall rains in 1996, unfavorable timing of runoff from parts of the Basin, and a major storm in April which dumped from 50-90 mm of water along the Basin.

Overall, forecasting was pivotal to both the prevention of property damage and loss of human lives. Recommendations for improved forecasting made by the International Joint Commission on the Red River Basin include suggestions for improved use of modeling and other technology, better basin-wide cooperation, careful analysis of unexpected overland flows in 1997, and better dissemination of easily interpreted forecast information to the public. Hopefully, these strategies will further reduce damages from high magnitude floods.

Today water control personnel have a responsibility to monitor flood situations, predict levels and timing, and communicate to the necessary authorities. Besides the common statistical format of reporting (e.g., anticipated levels of flow in cubic feet per second) personnel also use what are called "benchmarks". These benchmarks are past flood levels used as references to help communicate/anticipate to the public likely levels of damage by the upcoming flood to the public (Hannigan and Kueneman, 1974). One problem with this approach is that it can foster complacency in people who may have been spared in the referenced flood (i.e., the benchmark) because flood circumstances are often not duplicated nor predicted perfectly; this may leave them at more risk than they realize. If these properties flood there is increased and unnecessary damage.

5.3 Post-Flood Recovery

Post-flood recovery policy and practice in Manitoba is a complex issue. Government is concerned about the escalating costs of recovery. Yet the pressure to develop land in floodplains, the increasing value of property, lack of public involvement and understanding of flood risk, and the trend to finish basements contribute to increased damage payments. This paper will present some key practical and human issues confronting both the government and the public in the aftermath of a flood (Table 12).

Table 12 – Main characteristics of Post-Flood Recovery measure

Measure	• Activities, programs and policies which assist victims post-flood and restore property, including financial compensation and rehabilitation/restoration
Responsibility	• EMO Claims Department • Three levels of government • Charity Organizations
Issues	• Federal and Provincial governments provide post disaster assistance based on the Canadian Federal Disaster Assistance Arrangement. The cost sharing formula which outlines the federal contribution is as follows: 50% of total rehabilitation costs if the disaster costs are in excess of $1 per capita of provincial population, 50% for the next $2 of eligible provincial expenditures on assistance, 75% for the next $2, and 90% of the remainder. • Primary responsibility for recovery rests with the provincial level of government. • The willingness of government to pick up a significant amount of costs associated with recovery in recent decades has caused citizens to now see some types of compensation/assistance as government's *responsibility*. • Private and charitable funds are essential to full restoration of victims' households and businesses to pre-flood state. • There is no source of compensation for some types of damages e.g., flood-related hardship, lost wages. • Some citizens want full compensation from government, without a deductible, for damages they feel they incurred because of operation of the flood control system.
Issues	• Increasing land development and property values contribute to rising flood assistance payments

5.3.1. Evolution of Post–Flood Recovery Practice and Policy

In the Canadian portion of the Red River Basin, prior to the 1940s, there was no flood relief policy–government assistance was not available for so-called Acts of God. However, during the 1948 flood, private companies, volunteers, and charities raised tens of thousands of dollars; this constituted the first relief campaign to aid victims of the flood, but did *not* involve government. It was the Red Cross who figured most prominently and took a leadership role in post-flood recovery.

Then, in the large 1950 flood, Winnipeg's mayor started "The Mayor's Fund for Flood Sufferers" as the proportions of the crisis became evident. Contributions to this fund, later evolving into The Manitoba Flood Relief Flood, started pouring in from throughout the world. Private companies, charities and non-governmental organizations raised huge amounts of money and brought in items needed by victims.

A federal-provincial commission (i.e., the Carswell-Shaw Commission) was established in 1950 to assess flood damage and determine what would be the federal financial contribution to recovery costs. The fact of federal assistance for recovery had been established at the peak of the crisis when the federal government had declared a "national emergency". In that circumstance there was precedent for the federal government to then give assistance for what they termed "rehabilitation". The amount of assistance was based on covering a percentage of costs.

The provincial government, to facilitate the recovery process had set up a Red River Valley Board (RRVB) with local membership to lead in disaster rehabilitation. The board made decisions on how funds were to be disseminated to help rehabilitate victims, using some unknown formula to calculate the amounts granted to victims. The Red Cross no longer was the primary flood relief coordinators and a more formalized system was for the first time put in place. This meant better record-keeping and more stringent policy stances. The provincial government did calculate assistance funds using depreciation, but in 1950 did not require deductibles be paid. Many types of damages and losses were not covered.

Luckily, the monies raised by charity, through non-governmental contributions, and the generosity of others were enormous; this allowed victims who did not qualify for much assistance through the government to recoup most of their losses. Businesses, particularly, benefited from the raised funds, kept in the Manitoba Flood Relief Fund, because they did not qualify for much government assistance. No source of compensation was available, for hardship because of life disruption or the consequences of wage or income loss. This is a policy that continues up to today.

The 1950 flood was important in setting a precedent that the federal government would pick up a portion, and only a portion, of disaster assistance costs for flooding in the Red River Valley when a national emergency was declared. It also established that the province would be required to pick up a significant amount of the other costs, dependent on whatever rules it chose to institute. And clearly, in 1950, the restoration of many victims to a semblance of their previous life was highly dependent on the largesse of non-governmental sources of relief. With the establishment of government responsibility for some part of flood rehabilitation, the 1950 flood also heightened expectations in the valley that in future the government would compensate them for flood damages, hence lessening personal responsibility for living in the floodplain.

In 1970 a federal "Disaster Financial Assistance Arrangements" program was instituted to be administered by a Manitoba board. It operated under a series of very specific federal-provincial cost-sharing guidelines that were contingent on the magnitude of total flood costs. The cost-sharing formula consisted of 50% of total costs as the federal contribution to assistance if the disaster costs were in excess of $1 per capita of provincial population, 75% federal assistance for the next $2 of eligible provincial expenditures on assistance, 50% of the next $2, and 90% of the remainder.

Through successive floods, including the sizeable 1979 flood, the federal government was firm in its adherence to the 1970 cost-sharing formula. At a provincial level, victims were assisted through the Manitoba Flood Disaster Relief Board in the amount of 75% of eligible costs (to a maximum of $10,000) with a $2,000 deductible. Some items had depreciation deducted from the compensation amounts. In 1979 claims were made for personal property, livestock, and also evacuation expenses. Structural damage to buildings and erosion of farmland were in some cases compensated. Obviously, over successive floods, the nature and range of losses and expenses covered by government flood recovery assistance was being both expanded, formalized, and adopted into the culture of the Red River Valley.

5.3.2. The 1997 Flood

In the more recent 1997 flood, it becomes evident that the principles of flood recovery or "rehabilitation" established in 1950 and 1970 are still the model. This model, as it was manifest in 1997, has been subject to much public controversy.

One of the most contentious issues in flood recovery in 1997 was related to the way in which victims' damage claims were handled and settled. The Manitoba EMO Claims department, which administers the program, was viewed by many as bureaucratic and cumbersome. Further frustration was generated by policy and eligibility changes which occurred over a period of months, causing stress and uncertainty among victims.

However, it must be remembered that the task of EMO was enormous and unprecedented. They were inundated with applications and questions. They received approximately 5100 individual damage claims and 61 municipal claims. To date $150 million in damages has been disseminated, with an anticipated eventual total of $250 million. EMO administers a complex program which requires eligibility criteria and limitations in coverage. They also must negotiate with the federal government regarding cost sharing and what is and isn't eligible for federal contribution.

Another contentious issue, noted elsewhere in this paper, is the perception that government may have caused some properties to flood through their flood fighting activities. Victims who believe this feel that if their damages are largely manmade rather than natural, they should get full restoration of their lives without exception and without deductibles.

5.4 Land Use Regulation and Mapping

5.4.1. The Role of Land Use Regulation and Mapping

In general, floodplain management involves the adoption of land use regulations specific to a particular floodplain. The regulations are based on the assumption that there are certain areas of the land that will be subject to periodic flooding—and are consequently at-risk areas (Table 13).

Table 13 – Main characteristics of land use regulation and mapping measure

Measure	• Land use regulation refers to rules of practice and policy governing how land is used within a designated floodplain, as supported by government. Floodplain mapping activity complements land use regulation by delineating the area at risk during floods of specific magnitude; in Manitoba the 100-year flood level is used in regulation.
Responsibility	• Provincial government, with Federal input and legislation • Municipal government
Issues	• The use of land use regulation as a means of flood damage reduction has been slow to be effectively adopted in Manitoba • Inconsistencies abound in use of Designated Flood Area maps because it is at the discretion of the municipalities • Weak land use regulation has allowed for increasing residential development along the river south of the Floodway which is extremely vulnerable to flooding. • Poor enforcement of regulations has been an ongoing weakness; legislated ministerial powers have not been used in instances of non-compliance. • New legislation is now before the provincial government which is intended to improve the success of land use regulation by more clearly discouraging the building of structures which are not compliant, and improving the inspection process.

The regulations attempt to limit the use of the land to activities or structures which are suitable to the type and level of risk; thus the areas may be zoned for certain uses only. This non-structural approach is the least costly method of flood damage reduction if instituted prior to major development in a high-risk area (Environment Canada, 1993). It can clearly be an example of a proactive versus reactive approach to flood damage reduction.

Land use regulations are best developed once there has been sufficient floodplain mapping done to identify the vulnerability of various areas to flooding, and at what magnitude flood the threat exists. In Manitoba, the Designated Flood Area (DFA) maps are a representation of the best determination of water levels in a hundred-year flood. The Canadian Flood Damage Reduction Program established in 1975 was the impetus for development of flood maps; in Manitoba rural municipalities have been provided with these maps to aid in making decisions about future land development. The city of Winnipeg refers to the maps regularly in planning decisions; in rural communities the use of maps varies dramatically. The Water Resources Branch promotes the use the maps as much as possible, with varying degrees of success.

5.4.2. The Evolution of Land Use Regulation in the Red River Basin (1940-1998)

Non-structural measures such as land use management were not investigated in Manitoba until the 1950 flood, when the inappropriateness of some residential development finally became obvious. With the start of a comprehensive diking program in Winnipeg, it became evident that some homes were so close to the river that there could be no dike constructed between the home and river; the home would therefore be left outside of the boulevard dikes and vulnerable. In total over several neighborhoods, at least 129 properties (and perhaps closer to 240) were ultimately excluded in the 1950s from the protection of these urban dikes.

In the 1950s the government did buy some of these unprotected properties in Winnipeg. Those properties not purchased likely cost too much for government to buy outright (Bumsted, 1997, pg. 82). Some of these homes are today still at high risk and require assistance repeatedly during floods.

Public activism came to the fore as property owner associations asked government for compensation in lieu of their decreased property values resulting from their evident vulnerability to flood. No firm policy position was adopted by the federal and provincial governments with respect to vulnerable properties, although they refused in most cases to respond to pressure to financially compensate the properties excluded. The distinction between "have" and "have nots" in the issue of flood protection now also existed within the city of Winnipeg and not just between city and rural communities. These disparities set the stage for dispute and perceptions of social inequity which continue today in the wake of the 1997 flood.

It is noteworthy that two years after its conception, the Greater Winnipeg Diking Board (GWDB), after trying to deal with disputes about exclusions from the new diking system made "several strong pleas for floodplain zoning." (Bumsted, 1997, pg. 85). By trying to make decisions under complex and at times, highly emotional circumstances, the board had recognized a fundamental problem, i.e. that non-structural as well as structural measures would be necessary to address the issue of flood damage reduction in the Red River Basin. The GWDB made recommendations to implement zoning laws particularly in the neighborhoods of Fort Garry and St. Vital, where substantial residential growth was beginning. The recommendation was ignored, and growth in these communities escalated.

The focus throughout the 1960s was on structural measures, particularly with the construction of the sophisticated flood control system in Manitoba; several years of flooding did follow the completion of the Floodway in 1962 validating the need for its construction to protect Winnipeg. However, residents and communities south of the Floodway were being increasingly flooded.

As damages arose outside the city, flood relief was being regularly required of government. In response to these continuing high costs of flooding (even after the major structural works' implementation) the federal government and the Province of Manitoba signed three agreements in 1976. A dominant theme in the agreement entitled the "General Agreement Respecting Flood Damage Reduction", was a clear statement to reduce future flood payouts by government by primarily "discouraging development in flood-zones through withdrawal of mortgage guarantees and other financial measures" (Bumsted, 1997, pg. 98). A second agreement was for a flood mapping program to identify high risk areas and make this information available to potential residents and prospective developers. The agreement particulars were forged by a steering committee of provincial and federal representatives working cooperatively to reduce flood damage. Both senior governments stated the intent to avoid investing (directly or indirectly) in flood hazard areas, and policies since then have focussed on *avoiding* investment in flood hazard areas if such investment would increase future flood damages (Government of Canada, 1991).

The agreement's primary objective, i.e., to reduce future flood damages, was to be reached through both the above non-structural approach, and by constructing structural works for at-risk communities. The decision on whether to construct and *what* structural work to use was determined by whether benefits of the work was equal to or exceeded the cost. Most importantly though, the flood mapping program was to designate areas at risk from flooding be used to discourage inappropriate development in those areas. Unfortunately, in Manitoba (unlike some

Canadian provinces) municipalities were encouraged, *but not obligated*, to zone on the basis of flood risk mapping.

In the 1970s, a new demographic trend saw people moving in greater numbers from Winnipeg to rural areas just south of the city. Property in close proximity to the river was cheaper and aesthetically pleasing. The problem with this development became evident however when after the 1974 flood, 270 homes south of Winnipeg had to be moved out of the high risk area.

Further confirmation of the need for better land use regulation came in 1979, after that flood, because it was calculated that a large portion of the total cost of emergency measures and damages came from the new poorly situated construction. A new agreement to address such flood damages emerged in 1979, through the provincial–federal Special Damage Reduction Agreement which allowed individuals to flood proof their homes and buildings, build or raise dikes or, in rural areas particularly, relocate homes to within the protection of community ring dikes (Rannie, 1980). Floodproofing began to emerge as a significant non-structural damage reduction measure.

Thus from 1976 to 1979 there was finally a theoretical shift in emphasis away from strictly structural measures to inclusion of non-structural means of damage reduction. It took a recognition of the costs of flood damages to federal and provincial governments, even with structural measures in place, to prompt the philosophical shift in land use practice.

In 1979 provincial legislation also stipulated that homes in the Red River floodplain be 771 or 772 feet above sea level. And in 1980, for the first time, a community just beyond the floodway outside of Winnipeg (Grande Pointe) had caveats added to property titles respecting elevations. The elevations used were that of the flood of record or the 1979 flood level (IJC, 1997).

Also in 1979, Manitoba established and mapped the Red River Designated Flood Area in 1979 in accordance with the Canadian Flood Damage Reduction Program. This provided information to municipalities, communities, individuals, and businesses about flood vulnerable areas and the level to which structures must be built.

5.4.3. Current Land Use Regulations in Manitoba

The recent 1997 flood has influenced the boundaries of the Designated Flood Area in Manitoba and the floodproofing criteria for structures. In some communities, particularly in the southern part of the Basin, the changes are negligible; more immediately south of Winnipeg where water level predictions in 1997 were more inaccurate, building regulations will undergo a more significant change.

Prior to the 1997 flood, building permits in Manitoba stipulated that the main floor of a home with a basement must be 3 feet (1 metre) above the 1979 flood level. As of this past flood (i.e., 1997) all work for floodproofing standards are now at the 1997 flood level plus 1 meter for buildings. This makes 1997 flood the design flood. Dikes approved as part of the 1997 government sponsored flood-proofing program must also conform to a new standard – 1997 flood level plus 2 feet (0.6 metres) (IJC, 1997). New Designated Flood Area (DFA) maps are being generated reflecting the new criteria.

When Water Resources receives a building permit application in a high flood risk area, main floor and finished grade elevations are given according to the Flood Designation level of the area. They will itemize any concerns and make recommendations on how to reduce flood damage risk; there are no consequences for failure to comply. Notice of non-compliance is often not given out until well after the structure is completed.

In fact, the October 1997 Manitoba Natural Resources Submission to the Manitoba Water Commission noted that while regulation requires a notice *eventually* be sent to verify compliance/noncompliance, there is no set time period. The report states that compliance letters related to applications in 1988 and 1989 have been sent to all permit holders. This would put the notices of compliance/noncompliance eight or nine years behind construction, although the inspections themselves have largely been done. Received letters of non-compliance caused some problem in 1988-1989 because they advised people they may not be eligible for future compensation programs. Presumably, this "problem" has not been rectified in the intervening years (Manitoba Natural Resources Submission to The Manitoba Water Commission, 1997). Instead, the issue of noncompliance has been largely overlooked.

Municipalities have, in fact, a lot of autonomy in permitting residential and commercial development. Some Manitoba municipalities do not even have zoning by-laws. Some that do have by-laws do not include requirements related to elevations of structures. Other municipalities include flood risk assessment effectively in their decision-making. Overall the commitment to flood damage reduction through careful land use is inconsistent and arbitrary. There is also no mechanism to ensure that development permits given by municipalities are conditional upon a Water Resources Permit, even in the DFA.

The use of land regulations and zoning by-laws as a means of reducing flood damages requires not only creation of regulations and dissemination of information. It also requires enforcement of regulations both at a municipal and individual level. Sources interviewed feel this will take more evident political will, manifest through enforcement of floodproofing standards or clear consequences for those who allow inappropriate development.

In Manitoba, of a total of 881 permits issued prior to the 1997 flood, 535 were for residences. Of these, 362 were completed and inspected. Two hundred and six complied with the floodproofing criteria; one hundred fifty-six did not. Of the one hundred fifty-six (43%) that did not meet requirements, 125 (80%) did, however, have **main** floor elevations above the 100 year flood level. This level of protection likely reduced damages significantly.

The small portion of designated flood area that is *within the city of Winnipeg* is more carefully regulated; a building permit is not issued *until* the foundation is inspected and found to comply.

Land use regulation actually falls under Section 17 of the Water Resources Administration Act which also grants the Minister powers to cancel any development permit that does not comply with prescribed "floodproofing criteria". Ministerial powers to refuse flood protection or compensation based on failure to flood proof have never been used.

Section 17 of the Act also grants to the Minister the power to order removal of a "building, structure, or erection" in a designated flood area that contravenes the legislation or any "applicable floodproofing criteria". He/she can also have it removed if the owner fails to comply with regulations and may charge the owner for the costs of removal. The Minister's option of removal of non-compliant structures has "never been seriously considered" (Manitoba Natural Resources, Manitoba Submission to the Manitoba Water Commission, 1997).

It becomes evident that the legislation itself has strength; the problem lies in a lack of action to enforce the legislation to its full potential. In awareness of the problem, the Water Resources Branch of the Natural Resources Department is supporting a submission to the provincial government for new legislation which it is hoped will be passed in the next session of the house. This new legislation related to land use would allow:

1) Two inspections of building sites, one to occur right after the completion of the foundation, and the other upon total completion. This will allow errors in compliance to be corrected at the onset of building, and lessen the costs of compliance.
2) Caveats to be added to land titles to indicate that the property is in a DFA and is subject to building regulations. This may limit eligibility for flood disaster assistance in the event of compliance.
3) Wide dissemination of information on floodproofing requirements to prospective buyers and lending institutions; now such information is usually given only upon request.
4) Government to levy cumulative fines for non-compliance.

Overall, use of zoning regulation and land use practice as a strategy to mitigate flood damage in Manitoba has been compromised by poor enforcement. Federal-provincial agreements to encourage regulation and discourage inappropriate development which were begun in the late 1970s were then followed by more than a decade of dry years. The lack of apparent necessity made the political will to enforce regulation low. And much of the use of regulatory guidelines was at the discretion of municipal governments, resulting in significantly different levels of compliance throughout the Designated Flood Area. Now, the devastation of the 1997 flood has spurred government to revisit the issue of enforcement; hopefully, all levels of government, the private sector and the public will recognize the need for land use regulation if flood damages are to be contained in future. Otherwise, there will be excessive reliance on both permanent structural measures (such as the Floodway and ring dikes) and on costly temporary structural measures erected hastily during a flood.

The impact of land use regulation to date on the net economic value of floodplain occupancy would be difficult to calculate given poor enforcement and differences in local governments' use of the regulations. With increased enforcement and careful tracking of applications for development at the municipal level, it may be possible in future to obtain data and analyze it with the cooperation of the nine municipal governments and provincial government. Such information is not currently readily available.

5.5 Floodproofing

The purpose of floodproofing strategies is to reduce or prevent future damages and losses due to flooding. Floodproofing programs are instituted by government as an incentive to residents to protect their property. Various structural strategies such as diking, terracing, raising buildings can be covered by the program or, in some instances, floodproofing may include moving buildings to higher ground or to an altogether different location (Table 14).

Table 14 – Main characteristics of Floodproofing measures

Measure	• Floodproofing activities are meant to protect individual structures from flood damage; they include diking, terracing, raising buildings, relocation etc.
Responsibility	• Manitoba Water Resources Branch administers the program with the assistance of the Emergency Management Organization. The latter maintains the database of victims and their circumstances. Water Resources Branch provides both technical and financial assistance to communities, businesses and individuals who need help to flood proof.
Issues	• Since summer 1997 the current floodproofing program has been instituted, using the 1997 flood as the design flood. • Due to the large personal losses of some victims of the 1997 flood it is difficult for some victims to access sufficient funding to flood proof • The floodproofing program will be in operation for five years, with applications required within two years; however, the consequences (if any) of failing to flood proof are unknown if future damages are sustained.

5.5.1. Evolution of Floodproofing Programs in the Red River Basin (1960-1998)

Various floodproofing programs have been made available to residents of Manitoba since the 1960s. Then, the emphasis was on having rural residents raise buildings and dike individual properties to reduce flood damages. In 1979, floodproofing initiatives (city as well as rural properties) added relocation as an option in some few instances where structural measures were impractical.

5.5.2. Current Floodproofing Initiatives

More recent flood-proofing initiatives such as in 1996 and 1997 have included technical and financial assistance to residents to build, enhance ring dikes, or relocate. In 1997, floodproofing funds are available for up to 75% of costs subject to various cost ceilings which depend on the type of work required. Incentives are built into these newer programs because the 20% damages deductible is waived for the resident's disaster assistance claim, if they flood proof.

This issue of "incentives" is an important one. While it is easy to assume that the anticipation of another flood would be adequate incentive to flood proof, in the Red River Basin the overall frequency of reoccurrence of large magnitude floods is sufficiently low to allow complacency to return to the population in a very few years. This has been seen repeatedly.

5.5.3. Property Values

Perhaps for the above reason, several government sources remarked that property values in the Red River Basin are not significantly or negatively altered by proximity to the river or failure to flood proof, even outside of floodway protection. One expert did speculate that some of the properties just south of the floodway which were so badly flooded this past summer may have a large drop in market value for several years, particularly if they fail to flood proof and the anticipated caveats about the flood risk are attached to land titles in future. Further analysis of this issue is warranted. Property value impacts can be determined only with cooperation of the municipalities flooded because they have the detailed information on structural and property values required.

5.6 Flood Insurance

While the United States of America (since 1968) has favored flood insurance as a primary flood damage mitigation measure, Manitoba has focussed more on structural measures such as the Floodway and community ring dikes. Flood damage assistance to residents in Canada then favors public grants by government, supplemented by private charity rather than an insurance model (IJC, 1997).

As far back as the 1950 flood, the general philosophy was that floods, as Acts of God, were not covered by insurance. That year, those few individuals who did have insurance received additional assistance through the generous Manitoba Flood Relief Fund (MFRF), i.e., monies raised through donations. The amount received from MFRF was the difference between the insurance awards and the appraised value of damaged goods.

In 1958, when the Royal Commission on Flood Cost Benefit Analysis, considered flood insurance as an option, they dismissed a self sustaining flood insurance program as impractical (Bumsted, 1997).

Insurance companies were, however, heavily impacted by a flood in 1993. In this case, there was excessive surface water in the city of Winnipeg as the result of rain storms. This caused sewer backup. Insurance coverage was then available for this type of water damage on many household policies (although not for river flooding). Consequently, $200 million was paid out by insurance companies for flood claim damages. Now most household policies exclude sewer backup.

5.7 Final Comments on Nonstructural Measures in the Red River Basin

There are limits to the amount of flood protection offered by structural measures. The use of complementary non-structural measures can both maximize the efficiency of existing structural measures and reduce damages in vulnerable areas. Flooding is a complex phenomenon which requires a variety of technological, political and social strategies to reduce its negative impact. This requires creative and cooperative decision-making and planning using the expertise of many disciplines.

For long-range innovative and far-reaching solutions to be not only developed but successfully *implemented* means that jurisdictional responsibilities, particularly financial arrangements between levels of government, must be clarified; as well, enforcement of non-structural flood mitigation strategies must be done. Essentially the enforcement by government of regulatory strategies (e.g., zoning; building permits) would elevate the importance of flood awareness in the Red River Valley. Since a prevalent problem in the past has been complacency among the general public concerning flood preparedness, regulatory enforcement is one way to combat this disinterest. Another means would be financial or other incentives/disincentives to individuals and communities to make decisions that reduce their risk of flood damages.

Ultimately a strategy that assists individuals to act in their own self-interest, and problem solve when it comes to flood protection, rather than leaving it exclusively in the hands of government, will benefit Manitoba in the long run. Non-structural measures such as emergency or flood preparedness, are vitally important at the individual and community level. The unfortunate reality which must be acknowledged is that a flood of such magnitude that current structural measured are breached will occur every several hundred years. Non-structural measures of all types–those related to emergency preparation, flood recovery, land use regulation, floodproofing etc. all offer additional protection when carefully applied. They must be given more priority than they have to date both by government and the public. Anticipation of the "next" flood is a reality that must be acknowledged and prepared for within the Red River Basin.

6. CONCLUSION

There is a shortage of comprehensive information that can be used to assess the effectiveness of flood mitigation strategies in the Red River Basin over the last decades. Through review of records and interviews with government personnel, it is clear that information is scattered across different levels of government and departments, and is not well-organized. Questions about the effectiveness of mitigation strategies tend to be answered with "ballpark" figures, and in the case of structural measures, overall optimism.

It is also clear that much of the information necessary to determine effectiveness of various strategies is available only at a municipal level, through perusal of records and development plans. Yet there are nine municipalities in the Designated Flood Area, each with different approaches to flood risk management. A detailed analysis of the impacts of flood damage reduction strategies would require significant resources and municipal cooperation.

The following observations do, however, emerge out of this paper. It is evident that without the current flood control system protecting the city of Winnipeg, losses from floods since the late 1960s would be much greater in magnitude. This is quite generally accepted, although there are some people who maintain that the control system has increased their flooding. The resolution of this issue, which has existed for decades, remains unknown. Clearly, though, such victims would hold government liable for their full damages should the allegation be proven true. Unfortunately, the issue does foster conflict between some rural and urban residents.

With regard to the effectiveness of structural measures in the upper valley, there is a lack of concrete information available, yet communities damaged by the 1997 flood are planning diking initiatives. The long-term consequences of numerous home and community dikes on water movement in the rural landscape are unknown and warrant investigation.

Of the non-structural flood damage reduction measures, land use regulation warrants particular attention because, since 1975, federal-provincial agreements have expressed government intent to implement this measure more fully. Yet, as examination revealed, poor enforcement by authorities and inconsistent application of land use regulation by municipal governments has greatly reduced the effectiveness of this strategy in the Red River Basin. Newly proposed legislation with regard to land use, currently before government, will only be effective if these problems are addressed.

The floodproofing programs sponsored by the federal and provincial governments in past years have made a positive contribution to flood damage reduction. Both communities and individuals who floodproofed to the 1979 design flood level suffered less damages overall in 1997. However, floodproofing has its limitations, particularly evident when water levels exceed the standard hundred-year level or unpredicted overland flows occur.

The question of whether the government will continue to compensate victims who fail to flood proof is frequently posed; government practice, in contrast to policy statements, has been to *always* compensate regardless of floodproofing. In addition, while relocation is an option in the floodproofing program, it is rarely sought by victims. The emphasis in Manitoba is clearly on reconstruction, even in highly vulnerable areas.

The institutionalization of flood mitigation is a concern in the Canadian portion of the Red River Basin. Flood fighting, management of flood control systems, and responsibility for post flood recovery all rest largely in the hands of government, freeing the individual from a perception of responsibility until a crisis. This reduces the effectiveness of flood damage reduction initiatives.

Finally, it is evident that because of the recent flood, authorities are putting renewed effort into flood management activities. Hopefully, cooperation and exchange of information between departments and different levels of government will result in a rigorous analysis of which strategies warrant the input of financial and human resources in future. This should be a long-term goal.

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APPENDIX A

1. Manitoba Forecasting Program 1990
2. Hydrologic Forecasts and Condition Reports
3. Required Elevations for FDR Construction

1. MANITOBA FLOOD FORECASTING PROGRAM 1990

A. OBJECTIVE

- prediction of peak flows and stages for floods
- prediction of low flows and levels during drought
- prediction of runoff volume, especially for springtime
- prediction of lake and reservoir levels
- prediction of surface water supplies in general

B. SCOPE

- all of Manitoba with emphasis on agricultural regions
- flood forecasting for cities, towns, villages, agricultural lands
- Red River, Assiniboine River, Souris River, Saskatchewan River and 50 smaller watersheds
- Regular forecasts for seven lakes, seven reservoirs with others done on a request basis

C. DEVELOPMENT

- analysis of past floods, droughts
- formulation of snowmelt-runoff, rainfall-runoff relationships
- investigation of complex runoff models
- development of runoff forecasting and flood routing procedures for Manitoba watersheds

D. IMPLEMENTATION

- acquisition of data on soil moisture, snowcover, rainfall, streamflow, water levels using manual means, satellite data, radar
- liaison with engineers, water managers and flood fighters in Manitoba, Saskatchewan, North Dakota and Minnesota
- preparation of forecasts and dissemination to users

E. BENEFACTORS

- cities, towns, villages, municipalities
- Indian Bands, local government districts
- water managers
- flood fighters, such as Emergency Measures Organizations (EMO), Emergency Operations Centres (EOC) and rural municipalities (RM's)
- hydroelectric utilties
- private individuals

F. BENEFITS

- reduced flood damages through improved operation of flood control works, evacuation of goods, livestock and people, emergency diking, etc.
- more efficient use of water in lakes, rivers, reservoirs through supply/demand management
- reduced anxiety during floods and drought through public information

2. HYDROLOGIC FORECASTS AND CONDITION REPORTS
Manitoba Natural Resources

1. **Type:** Water Supply Conditions and Outlook for Manitoba

Date/Frequency: During first week of each month

Remarks: Reviews weather conditions, evaporation, snow cover for the past month. Provides latest available reservoir storages, lake levels, streamflows, aquifer levels and compares data to previous year and to long-term averages and extremes. Indicates actions being taken to meet water needs/uses and provides and outlook on water supplies and the likelihood of shortages.

2. **Type:** Spring peak stage and discharge forecasts for the Red, Assiniboine and Souris rivers and a qualitative outlook regarding the flood potential on other river systems.

Date/Frequency: Third week of February and March.

Remarks: Mailed or faxed to all municipalities, cities, towns, local government districts, Indian bands, emergency measures organizations and other users within and outside the government. A news release is distributed to the news media.

3. **Type:** A numerical forecast of spring peak discharges for large and small watersheds in southern Manitoba, as far north as The Pas.

Date/Frequency: Last week of March.

Remarks: Forecasts are given for the lower decile, median and upper decile spring weather condition. Distributed to flood fighters, senior management, Water Survey of Canada.

4. **Type:** Flood sheets showing present conditions and forecasted peak stages and dates.

Date/Frequency: Prepared daily during spring runoff when there is a significant flood threat or actual flooding.

Remarks: Includes comparative flows and stages from past floods, bank full capacities, elevation of dikes etc. Distributed daily by fax or personal contact to flood fighters, emergency measures organizations, senior managers and politicians, others. News releases prepared for media whenever situation changes significantly.

5 **Type:** Forecast of river levels in City of Winnipeg.

Date/Frequency: Daily during spring runoff and sum.

Remarks: Predicted stages for the next three days and the anticipated flood crest. Purpose is to reduce damages and flood fighting costs through more efficient planning and staff deployment.

6. **Type:** Water supply forecasts for reservoirs and controlled lakes.

Date/Frequency: Monthly or quarterly, depending on hydrologic conditions.

Remarks: Emphasis is usually on Lake Manitoba, Dauphin Lake, Shellmouth Reservoir. Forecast lead time varies from one to six months, depending on conditions and time of year. Forecasts for other reservoirs done mainly during drought when water supplies are in jeopardy. Used internally to optimize operation of control structures.

7 **Type:** Drought Emergency Reports

Date/Frequency: Monthly or weekly during times of severe drought.

Remarks: In-depth reports on surface water and ground water supplies, shortages, trends, emergency actions etc. Prepared for interdepartmental drought committees at the technical and senior management levels.

3. REQUIRED ELEVATIONS FOR FLOOD DAMAGE REDUCTION CONSTRUCTION PROGRAM

The 1997 Flood will be used as the design flood. The following criteria are based on Manitoba Regulation 266/90 and are minimum standards.

House with a basement – the main floor equal to the 1997 level plus 3.0 feet. The fill elevation (grade) equal to the 1997 level plus 2.0 feet.

House without a basement – the main floor equal to the 1997 level plus 2.0 feet, the fill at 1997 plus 1.0 foot.

House raised on posts or piles – the main floor equal to the 1997 level plus 5.0 feet, the finished grade at the foundation not more than 3.5 feet below the 1997 level.

Ring dikes- 1997 level plus 2.0 feet.

Livestock barns – the floor equal to the 1997 level plus 2.0 feet, fill 1997 plus 1.0 foot. (This is a change from the regulation which required only one foot of freeboard above the design flood. It became apparent during this year's flood that the types of livestock operation prevalent in the valley, hogs, poultry, and dairy, are very sensitive to disruption and require a higher level of protection).

Attached garages, granaries, farm machinery sheds, and any other buildings used for the storage of agricultural produce, workshops and sheds used for the storage of immovable equipment or material or hazardous material – the floor elevation equal to the 1997 level plus 1.0 foot, fill at the 1997 level.

Detached garages – Floor may be up to 3.0 feet below the 1997 level, but the structure should be waterproof up the 1997 level.

AN ASSESSMENT OF A PROPOSED FLOODPLAIN MANAGEMENT EVALUATION METHOLODOGY: A CASE STUDY OF THE CREDIT RIVER WATERSHED

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ABSTRACT

This pilot study assesses the evolution of Canada's Flood Damage Reduction Program, and the resulting effects on the natural functions of wetlands for the Credit River watershed in Ontario. A content analysis of municipal official plans, and annual reports and other documents from Credit Valley Conservation (CVC) provides a measure of the extent to which agencies in the Credit River watershed recognize relationships between natural area protection and floodplain management. More detailed field investigation of floodplain management activities took place in three communities: Mississauga, Halton Hills and Orangeville.

The study confirms that floodplain mapping and land use regulation have been important aspects of floodplain management in the Credit River. Canada's Flood Damage Reduction Program has had impacts on policy and practice relating to the protection of significant natural features such as wetlands. However, it is very difficult to determine the specific contribution of the program to increased concern for fragmentation of wetlands by political boundaries, public support for watershed functions, protection of environmentally sensitive areas and stormwater management design standards.

1. INTRODUCTION

This report presents the findings of a pilot study that assessed the proposed floodplain management evaluation methodology originally articulated in a proposal by Newton *et al.* (1996) and refined by Montz *et al.* (unpublished). The proposed methodology is designed to allow for a cross-national evaluation of floodplain management in Canada, the United States, and Mexico. Two distinguishing characteristics of the proposed methodology are that it incorporates a longitudinal component, and that it addresses the impacts of floodplain management broadly by focusing on the areas of *occupancy*, *economic impacts*, and *natural area protection*.

The pilot study summarized here assessed the methodology by using it to gather preliminary data relating to one country's program, Canada's Flood Damage Reduction Program (FDRP), and to one dimension (natural area protection). This assessment provides grounds for suggesting that further refinement of the proposed methodology is warranted, and that its application to the other countries and dimensions of floodplain management would be worthwhile.

The report is organized as follows. In Section 2, a brief overview of the proposed methodology is provided. Section 3 outlines the design of the pilot study assessment. Findings from the pilot study are presented in Section 4. Conclusions, recommendations and implications are addressed in Sections 5 and 6.

2. OVERVIEW OF THE PROPOSED METHODOLOGY

The floodplain management evaluation methodology originally proposed by Newton *et al.* (1996) and refined by Montz *et al.* (unpublished) focuses attention on three questions:

1. What is the effect of flood damage reduction programs on *floodplain occupancy* as measured in 1970, 1980, 1990 and 2000?
2. What is the effect of flood damage reduction programs on *net economic value* of floodplain occupancy as measured in 1970, 1980, 1990 and 2000?
3. What is the effect of flood damage reduction programs on the *natural functions of wetlands* as measured in 1970, 1980, 1990 and 2000?

Newton *et al.* (1996) suggested that these questions should be addressed in the context of eight areas addressed by floodplain management programs (referred to as "interventions"). These include: (1) floodplain mapping, (2) public education, information and awareness, (3) regulation of land use, (4) performance standards for buildings, (5) retrofitting, (6) insurance, (7) relocation of buildings, and (8) disaster relief. For each of these interventions, measurement criteria were suggested relating to the three questions posed above (Table 1). Additionally, Newton *et al.* (1996) suggested a preferred methodology and discussed the availability of data and the level of knowledge for each adjustment.

The challenge in the pilot study was to operationalize enough of the proposed methodology to determine whether or not it would be worthwhile and feasible to use it for larger cross-national comparisons. To accomplish this objective, the methodology emphasized the pertinent interventions relating to the impacts of the Canadian federal-provincial Flood Damage Reduction Program on the natural functions of wetlands. *Since this is a pilot study that focused on assessing the methodology, readers are cautioned that the empirical findings are preliminary rather than definitive in nature.*

Table 1. Program Intervention and Measurement Criteria by Research Question in Newton *et al.*'s Proposed Methodology

Program Intervention	A. Occupancy	B. Net Economic Value	C. Natural Functions
1. Floodplain mapping	• *Not applicable*	• *Market value of property/lands*	• *Artificial fragmentation of watersheds by political boundaries*
2. Public education, information and awareness	• *Decisions not to locate or build* • *Decisions to move out* • *Decisions to retrofit*	• *Decisions to purchase insurance* • *Value of retrofitting*	• *Public support for watershed functions*
3. Regulation of land use zoning	• *# of communities with floodplain zoning* • *# of floodplain structures with respect to the whole community* • *# of "protected" structures* • *Floodplain population with respect to the whole community* • *Type of structures in floodplain (commercial, residential, public)*	• *Market value of buildings in floodplain compared to market value of buildings in the whole community* • *Market value of buildings in "protected" areas* • *Shifts in tax base*	• *# of communities with natural use zoning* • *Floodplain acreage zoned for natural use* • *Miles/km of protected stream*
4. Performance standards for buildings	• *# of compliant structures with respect to floodplain structures* • *Population in non-compliant structures*	• *Market value of compliant structures* • *Market value of non-compliant structures*	• *# of communities with development design standards for stormwater management* • *Site alteration to meet performance standards*
5. Retrofitting	• *Decisions not to locate*	• *Market value with respect to previous value* • *Damage avoided*	• *Not applicable*

6. Insurance	• *# of floodplain policies* • *# of non-floodplain policies* • *Decisions not to locate* • *Decisions to locate*	• *Disaster assistance paid per event* • *# of claims paid on subsidized policies* • *# of repetitive claims* • *Value of repetitive claims*	• *Decisions to build*
7. Relocation of buildings	• *# of structures removed with respect to # built and # in floodplain*	• *Market value of structures removed* • *Value to public of cleared space* • *Shift in tax base*	• *Acreage returned to natural functions*
8. Disaster relief	• *Decisions to relocate* • *Decisions not to relocate*	• *# of disaster assistance payments* • *Value of disaster assistance payments* • *# of repeat disaster assistance payments* • *Value of repeat disaster assistance payments*	• *Decisions to rebuild infrastructure* • *Decisions not to rebuild infrastructure*

3. PILOT STUDY METHODOLOGY

The proposed floodplain management evaluation methodology is broad in scope and extremely data intensive. Consequently, in this pilot study it was necessary to narrow the focus considerably. Several considerations shaped the design of the pilot evaluation.

1. Considerable research has been conducted relating to net economic impacts of the FDRP; see the review by de Loë and Mitchell (1995). Similarly, numerous studies relating to the occupancy dimension have been conducted (e.g., Shrubsole *et al.* 1995; 1997). Less well-understood is the link between floodplain management and protection of natural areas. Research by Millerd *et al.* (1994), and more recently by Wojtanowski (1997), who implemented an evaluation methodology proposed by de Loë and Mitchell (1995), suggests that the FDRP has had important impacts relating to the protection of natural areas and functions -- and that these impacts are difficult to quantify. Consequently, for the pilot study it was thought appropriate to emphasize the natural functions research question of the proposed methodology.
2. It was accepted that temporal aspects associated with the implementation of flood damage reduction initiatives should be incorporated. However, it was not thought feasible in the context of a pilot study to implement the decade-by-decade analysis (i.e., 1970, 1980, 1990, and 2000) of the proposed methodology. Therefore, in the pilot study, data were gathered for the present and for various "past" period. It was not possible to use one definite past period (e.g., 1970) because, for the various study sites, data were not always available for the same time period.
3. The spatial scope of the pilot study had to be manageable, given the time and funds available. It seemed appropriate to select communities within one major watershed. In an Ontario context, this had the added benefit of limiting the study to the jurisdiction of one conservation authority.
4. A final consideration that shaped the design of the pilot assessment is that the field work had to be completed between 1 July 1997 and 31 August 1997, and within the available budget of $10,000.

3.1 Overview

The methodology used in this pilot study combined a general analysis as well as a focused, specific analysis. Both of these analyses took place within the Credit River watershed. For breadth, a content analysis was performed of planning and other official documents created by seven municipalities and Credit Valley Conservation, the pertinent conservation authority. For depth, a detailed investigation of natural functions criteria in three communities was performed. Two research assistants were hired to conduct the research under the supervision of the authors. Danuta Wojtanowski conducted the focused field investigations, while David van Veen conducted the broader content analysis. The following sub-sections provide details on the following aspects of the pilot study methodology:

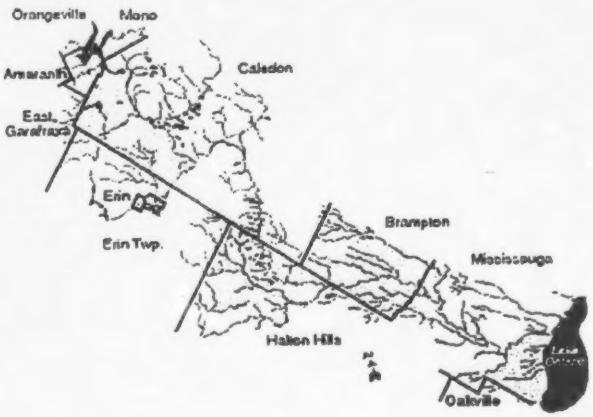
- Selection of a case study area;
- Content analysis procedures; and
- Field research.

Findings are summarized in Section 4.0.

3.2 Case Study Area

The Credit River watershed (Figure 1) was selected for detailed analysis due to its relatively small size, its close proximity to the field assistants who were located in Guelph and Etobicoke, and the type of settlements that it contains. The watershed has an urbanized southern portion (including the cities of Mississauga and Brampton), a rural central portion (including the Township of Caledon), and small but growing communities in its northern (Orangeville) and western (Halton) portions. This variety in settlement types provided an opportunity to evaluate the methodology in areas where different pressures exist on the floodplain. The rationale for selection of specific municipalities is discussed in the following sections.

Figure 1: Study Area



Source: Credit Valley Conservation (http://www.mississauga.com/CVC/mission.html)

3.3 Content Analysis

Content analysis has been defined as "a research technique for the objective, systematic and quantitative description of the manifest content of communication" (Berelson, 1952, 18). Although Newton *et al.* (1996) did not identify content analysis as one of the primary sources of data, the authors judged that in this pilot study it would be appropriate to use the technique to identify the extent to which agencies in the Credit River watershed recognize relationships between natural area protection and floodplain management.

Selection of Documents for Content Analysis

The extent to which agencies in the Credit River watershed recognize relationships between natural area protection and floodplain management was assessed by analyzing (1) municipal official plans, and (2) annual reports and other documents from Credit Valley Conservation (CVC). The presence of statements connecting floodplain management and natural areas in these documents does not necessarily mean that this relationship is addressed in practice. However, at minimum it suggests some level of awareness and concern. Additionally, planning practices should (ideally) be in conformance with official plan policy statements. A content analysis of plans and annual reports was important for another reason. The temporal component of the proposed methodology was addressed in this pilot study by analyzing current and past plans and reports. A greater frequency of references to floodplain management and natural areas in current versus old plans would suggest increased awareness, which potentially could be attributed in part to the FDRP.

Table 2 summarizes the municipal documents analyzed. Municipalities are divided into "local" and "regional" governments. In Ontario, the official plans of local governments within a regional government structure must be in conformance with the regional government's plan. In Table 2, the respective regional government is indicated in parentheses for each local government. Only Orangeville is not part of a regional government structure. These municipalities represent a broad cross-section of the types of settlement in the Credit River watershed.

Ideally, official plans from two time periods would be used. Plans from 1994 to 1997 represent the post-floodplain mapping phase, while plans from 1985 and earlier represent the pre-floodplain mapping phase. Ontario joined signed the federal-provincial FDRP agreement in 1978. Mapping for the study communities in the Credit River watershed took place in the early 1980s. Therefore, bracketing around 1985 addresses the temporal component of the research. Unfortunately, it was not possible in all cases to use pre- and post-1985 plans. In the case of Caledon, a pre-mapping plan not available. The 1991 plan was used because Caledon apparently has not changed its floodplain management provisions significantly from the 1979 plan (which could not be located by municipal staff when they were requested to do so). Similarly, for the Region of Peel, an earlier plan was not available. The Region's first official plan was created in 1996. Prior to 1996, the Region of Peel relied upon provincial policy statements for planning guidance.

Table 2: Municipal Data Sources

Type	Municipality	Documents Analyzed	Population (As of 1996)
Local Governments	Mississauga (Peel)	• 1997 Official Plan • 1981 Official Plan	55,900
	Brampton (Peel)	• 1997 Official Plan • 1984 Official Plan	278,160
	Halton Hills (Halton)	• 1994 Official Plan • 1971 Official Plan	38,763
	Caledon (Peel)	• 1997 Official Plan • 1991 Official Plan	38,894
	Orangeville	• 1994 Official Plan • 1972 Official Plan	20,605
Regional Governments	Halton	• 1995 Official Plan • 1978 Official Plan	315,557
	Peel	• 1996 Official Plan • See provincial policy statements	879,100

Municipal official plans were only one source of data for the content analysis. The second source was reports and studies prepared by the principal local water management agency, Credit Valley Conservation. For the CVC, data sources included the following:

- Annual reports for 1975, 1980, 1985, and 1991. These provided a temporal perspective.
- Miscellaneous strategies and policies, including the *Water Management Strategy*, Phase I and II (CVC 1991; 1992); the *Floodplain Management Policy* (CVC 1994); and the *Valleyland and Watercourse Protection Policy* (CVC 1992).

The only provincial policy statement examined was the one for 1978. This was used as an early benchmark for the Region of Peel case.

Content Analysis Procedures

Content analysis can take many forms. Some studies use keyword dictionaries and count the number of occurrences of certain words and phrases. Others measure the amount of space devoted on a page to particular themes. The content analysis performed in the pilot study was more straightforward. Each occurrence of a sentence, paragraph, or section addressing one of the natural functions criteria listed in Table 3 was counted. These "hits" were mutually exclusive. In other words, any particular reference to one of the criteria was counted either as a sentence, as a paragraph, or as a section. However, some "hits" pertained to multiple criteria.

This analysis allowed for an assessment of the relative importance of certain aspects of floodplain management during two time periods for each municipality and for the CVC. Notice that two interventions listed in Table 1 are not used: retrofitting and insurance. The former is not applicable to the natural functions question, while the latter is not pertinent in a Canadian context. (Commercial flood insurance can be purchased in Canada. However, residential flood insurance cannot be purchased in Canada, and is not provided by any government, as is the case in the United States.) Additionally, although all the criteria are listed in Table 3, not all of the specific criteria were appropriate relative to the content analysis. For instance, the text of official plans did not contain data relating to the size of the floodplain areas zoned for natural use, or the size of areas returned to natural functions. Data such as these were gathered in the parallel, detailed investigation (below).

Table 3: Natural Functions Criteria for the Content Analysis and Field Investigation

Program Intervention	Criteria
Floodplain mapping	Artificial fragmentation of watersheds by political boundaries
Public education, information and awareness	Public support for watershed functions
Regulation of land use zoning	Natural use zoning in the community Floodplain acreage zoned for natural use* Miles/km of protected streams*
Performance standards for buildings	Presence of standards for stormwater management Policies relating to site alteration to meet performance standards Policies prohibiting site alterations in floodplains
Relocation of buildings	Acreage returned to natural functions*
Disaster relief	Decisions to rebuild infrastructure* Decisions not to rebuild infrastructure*

* No data found for these criteria in the content analysis component of the study.

3.4 Field Investigation

Field investigation complemented the content analysis by providing greater depth for selected communities. Detailed investigation of floodplain management activities took place in three municipalities (Figure 1): Mississauga, Halton Hills, and Orangeville. Mississauga is a large, urbanized city in the southern portion of the watershed. The towns of Halton Hills and Orangeville are small but growing municipalities in the central and northern portions of the watershed. These communities have experienced substantial growth pressure, and have a relatively large portion of their jurisdiction designated as open space, hazard land or environmentally sensitive areas. They also have completed FDRP mapping in the early 1980s (Table 2).

For each of these communities, combinations of interviews with municipal and conservation authority officials, analyses of maps, reviews of studies, and analyses of permits were used to gather data relating to the program interventions listed in Table 3. In several cases, the field researcher broadened the interpretation of the criteria listed in Table 3.

Analysis of Maps and Reports

Two types of analyses of written sources of information took place. First, maps contained in various documents identified land uses permitted along riverine areas. Of relevance to this study were lands designated as Environmentally Sensitive Areas (ESAs), Green Lands, Open Space and Hazard Land in official plans. Since a separate "floodplain" designation is not used in the study area, it is not possible to associate all changes in designation to the FDRP or any other specific water management initiative. The areas of natural areas identified in maps were calculated using figures provided in accompanying reports.

Interviews

In addition to these written and mapped sources, interviews were conducted with relevant and accessible officials in the Credit Valley Conservation authority and the Halton Region Conservation Authority, and the municipalities of Mississauga, Halton Hills, and Orangeville. (Officials at the Halton Region CA were interviewed because the Town of Halton Hills lies partly in the jurisdiction of both authorities.) The interviews were open-ended. Officials were asked questions that provided information relating to the program interventions and specific criteria listed in Table 3. Interviews took place between 1 July 1997 and 15 August 1997. Since this period coincides with the summer vacation season, some relevant officials were unavailable.

Permits

Building permits in the Town of Orangeville were used to gather data for the relocation of building interventions.

4. RESEARCH FINDINGS

4.1 Findings for Specific Program Interventions

Findings for the specific program interventions are discussed in this section. Data sources for each intervention are summarized in Table 4. Details regarding the general categories of data sources were provided in Section 3.0.

Table 4: Program Interventions and Principal Data Sources for Field Investigation

Program Intervention	Principal Data Collection Technique(s)
Floodplain mapping	Interviews Content analysis
Public education, information and awareness	Interviews Content analysis
Regulation of land use zoning	Cross-referencing of maps Review of maps and studies Interviews Content analysis
Performance standards for buildings	Interviews Review of studies Content analysis
Relocation of buildings	Analysis of building permits Interviews
Disaster relief	Interviews

The discussion in the following section emphasizes the municipal official plans. However, documents produced by the Credit Valley Conservation and the provincial government were also analyzed (Table 5). These indicate some concern for the pertinent program intervention criteria, but are not drawn upon heavily in the discussion that follows. By definition, conservation authorities are concerned about floodplain management and natural areas. Hence, more significant is the extent to which municipalities address these areas.

Table 5. Summary of Analysis of Credit Valley Conservation (CVC) and Provincial Government Documents

Frequency of Occurrence of Statements Relating to Specific Criteria by Program Intervention for CVC Documents and 1978 Provincial Policy Statement

Program Intervention and Criteria		**CVC Annual Reports**				**CVC Floodplain Management Policy 1994**	**CVC Valleyland and Watercourse Protection Policy**	**CVC Water Management Strategy Phase I and II**	**Provincial Policy Statement (1978)**
		1975	**1980**	**1985**	**1990**				
Floodplain mapping	Artificial fragmentation of watersheds by political boundaries	1		1		1		1	2
Public education, information and awareness	Public support for watershed functions					1			4
Regulation of land use zoning	Presence of natural use zoning						2	3	4
Performance standards for buildings	Storm water management design standards							5	
	Site alteration to meet performance standards	3				10			8
	Prohibition of site alteration in floodplain	1		1		9	2		9

4.1.1 Floodplain Mapping

Conservation authorities ensure that flood-prone areas are identified through mapping exercises, and that they are designated in official plans as environmentally sensitive areas, hazard lands or open space. According to respondents from the Credit Valley and Halton Region Conservation Authorities, member municipalities have always agreed to appropriately designate areas identified through mapping exercises. However, previous research suggests that concerns regarding the accuracy of these mapping exercises is warranted (Shrubsole *et al.*, 1997).

The respondents suggested that, in the recent past, municipalities have been eager to designate areas as "natural" in response to a perceived high level of community support. This is supported by the content analysis (Table 6), which shows that most municipal official plans contain numerous references to the issue of fragmentation of watersheds by political boundaries. Indeed, there were many references to the importance of natural systems, including watersheds, in these plans -- although these references were not catalogued in this study unless they pertained to floodplain management.

In cases where municipalities shared wetlands or other important natural areas, conservation authorities played a coordinating role. For example, if municipal zoning for a shared feature was incompatible, respondents suggested that conservation authorities would encourage appropriate zoning changes.

Table 6: Frequency of Occurrence of Statements Relating to Specific Criteria for Program Interventions by Municipality and Plan Year

Program Intervention and Criteria		Municipality												
		City of Mississauga		Town of Halton Hills		City of Brampton		Town of Caledon		Town of Orangeville		Region of Halton		Region of Peel
		1984	1997	1971	1994	1984	1997	1991	1997	1972	1994	1978	1995	1996
Floodplain mapping	Artificial fragmentation of watersheds by political boundaries	3	2	4	2	1	6	5		3	8	2	1	3
Public education, information and awareness	Public support for watershed functions	1	4						3				2	
Regulation of land use zoning	Presence of natural use zoning	7	4	3	4	3	7	4	5	2	2	4	9	11
Performance standards for buildings	Storm water management design standards	2	5		3	1	2				2	1	3	1
	Site alteration to meet performance standards	1	2							1	5			
	Prohibition of site alteration in floodplain	5	11	2	2	4	2	7	8	2	3	5	4	4

4.1.2 Public Education, Information and Awareness

Interviews with officials in the three study municipalities suggest that the pertinent conservation authority is the source of advice and information relating to floodplain management and development. Officials interviewed suggested that, for the most part, municipalities do not take part in public education or the provision of information to the public *regarding floodplain areas*. Where public education takes place, it tends to relate more to water generally. This conclusion is supported by the content analysis of municipal official plans. Among the plans analyzed (Table 6), only three municipalities addressed public education relating to water. For example, under its Healthy Communities Policy for Water, the 1995 Official Plan for the Region of Halton includes the following objectives:

- To increase public awareness of the importance and value of an adequate, sustainable supply of clean water for both human use and the natural environment.
- To increase our collective knowledge of the water resources in Halton.
- Halton Region's objective relates to water generally, rather than to watershed functions and floodplain management. In contrast, The Town of Caledon's 1997 plan contains an ecosystem planning objective which relates to public education of watershed functions:
- To foster public awareness and education regarding Caledon's environment including this Plan's ecosystem principle, goals and objectives.

Neither conservation authority reported the formation of public committees or groups specifically related to the question of watershed functions. However, according to a 1996 survey conducted by the City of Mississauga, public perception of the importance of natural areas is high. Approximately 88 percent of respondents in this survey indicated a willingness to participate directly in efforts to enhance, preserve and restore the remaining natural areas in Mississauga. This may account for the presence of four statements in the 1997 Mississauga official plan relating to public support for watershed functions (Table 6).

The FDRP allocated some funds for the preparation of the Public Information Flood-Risk Maps, which differ in scale for various regions. Use of these maps is an obvious measure of the contribution of the FDRP to public education and information regarding watershed functions. In Ontario, the FDRP public information maps are kept by local conservation authorities. There is no consistent use of the mapping as a means of informing the public about flood and/or natural area management. For instance, CVC has been reluctant to use the 1:25,000 scale public information maps for these purposes, because it believes that their scale and coverage are unsatisfactory. Instead, CVC officials rely on the more detailed FDRP maps, at the 1:2,000 scale. In contrast, the Halton Region Conservation Authority frequently uses the public information maps for public inquiries relating to floodplain issues, and during public meetings such as ones relating to sub-watershed studies.

4.1.3 Regulation of Land Use

The most common terms used for natural areas, which often includes flood-prone lands, are: Environmentally Sensitive/Significant Areas (ESAs), wetlands, and Areas of Natural and Scientific Interest (ANSI). These categories are often defined as: land and water areas containing natural features or ecological functions of such significance as to warrant their protection in the best long-term interests of the people and environment.

For the content analysis, only the presence or absence of statements relating to natural use zoning was measured. The Official Plans analyzed did not contain specific reference to the floodplain area zoned for natural use, or to the number of kilometres of protected streams. All official plans contained references to some type of natural use zoning (Table 6).

During the field investigation, the number of communities with natural use zoning was counted, and the size of floodplain areas zoned for natural use was measured. It was not possible to measure the length of protected streams. Note that the concept of "communities" is problematic. Orangeville is treated as one "community" by its planners. However, in both Mississauga and Halton Hills planners identified distinct "communities" within the municipal boundaries. For example, Halton Hills treats hamlets such as Glen Williams as "communities" for planning purposes.

Natural Use Zoning

Field investigation determined that all three municipalities selected for detailed study had some type of natural use zoning. Additionally, it was evident that some municipalities recognized natural areas in official plans prior to establishing specific regulations. For example, the Town of Orangeville recognized "stream corridors" as natural areas in its 1985 plan, but has yet to create by-laws to protect these areas. During the content analysis of official plans, considerable reference to natural use zoning was evident in both old and current plans (Table 6). A trend towards increased reference to these zones is evident, but in some cases older plans have more references than newer ones (e.g., City of Mississauga). Plans do not indicate whether or not natural use zoning is a consequence of participation in the FDRP.

Floodplain Area Zoned for Natural Use

The first stage in identifying the floodplain area zoned for natural use is determination of the total area zoned for natural use. These figures were calculated based on data contained in studies conducted for natural areas. For Mississauga, 335 ha of ESAs existed in 1979, while 763.2 ha existed in 1996. For Halton Hills, there were 1,110 ha of ESAs in 1978, and 1,714 in 1991. For the Town of Orangeville, detailed studies did not exist. However, portions of 3 ESAs have been zoned. It was not possible to complete the next stage: identification of the proportion of these areas within the floodplain. This would have required an analysis using map overlays, or even better, a geographic information system.

4.1.4 Performance Standards for Buildings

Table 1 shows two specific criteria for this program intervention:

- # of communities with development design standards for stormwater management, and
- Site alteration to meet performance standards.

These were supplemented with a third criterion: number of communities prohibiting site alterations in the floodplain.

Number of Communities With Development Design Standards for Stormwater Management

During the field investigation, it became clear that the first criterion was not relevant, because storm water management facilities do not necessarily exist in the floodplain. This issue is addressed further in section 5.1.4. For the sake of completeness, references to storm water management were tabulated in the content analysis (Table 6). Note that the statements refer to storm water management, but do not necessarily pertain to design standards. Only the following plans included explicit design standards for stormwater management: City of Mississauga (1984 and 1997), Town of Halton Hills (1994), City of Brampton (1984 and 1997), Town of Orangeville (1994).

Site Alterations to Meet Performance Standards

Buildings that are constructed in areas designated under the FDRP as flood-prone areas have to be in compliance with the standards set out by the Provincial Floodplain Policy in 1988. Prior to that, the Floodplain Criteria of 1979 set guidelines for construction in Ontario's floodplains. Only new development, or additions to the old structures, must be floodproofed to the regional storm (or the 100-year flood) level. Halton Region CA and Credit Valley Conservation both conducted physical works for floodproofing. For example, in Mississauga, the CVC acquired six properties in the 1980s and built various structures.

Number of Communities Prohibiting Site Alterations in the Floodplain

None of the municipal and conservation authority officials interviewed could recall a case where site alterations in the floodplain for floodproofing had been prohibited. However, as the content analysis (Table 6) shows, the current and past official plans for all the municipalities included statements relating to restrictions on site alterations in the floodplain. These statements include restrictions on development in the floodplain.

4.1.5 Relocation of Buildings

Using aerial photographs, changes to building patterns in flood-prone areas have been calculated in previous studies (Shrubsole *et al.* 1995; 1997). This pilot study examined how building permit records might be used to address this issue. For the Town of Orangeville, building permits for the last decade were searched to determine if any cases dealt with the relocation of buildings out of the floodplain. In the 64 cases examined, none related to the relocation of a building. Indeed, because the Town of Orangeville uses a two zone floodway-flood fringe concept, and allows development in the flood fringe that is in accordance with floodproofing regulations, there was an increase in the number of structures built in the floodplain. These findings were confirmed more generally during interviews with municipal and CA officials, who could not recollect any cases of the removal and/or relocation of structures from the floodplain, except for old mill dams. Furthermore, these officials indicated that no record is kept on how many structures actually are in the floodplain, except for data collected by FDRP-related studies in the 1980s.

4.1.6 Disaster Relief

For this intervention, the issue is whether or not damaged infrastructure in sensitive areas of the floodplain (e.g., wetlands) are rebuilt following a flooding event. In the field investigation, it was determined that no significant flooding disasters have happened to the study municipalities since the initiation of the FDRP. Therefore, municipal officials were unable to recollect whether or not disaster relief had been provided for rebuilding infrastructure in wetlands in the floodplain. However, it was noted that in cases of minor flooding, the pertinent conservation authority coordinated relief work. In the case of spring ice-jams in Churchville, no financial relief was provided, and no reconstruction of damaged parts of buildings was allowed.

4.2 Summary

The purpose of this pilot research was to assess the proposed floodplain management evaluation methodology by trying to use it in a specific watershed. The research confirms that floodplain mapping and the regulation of land use have been important aspects of floodplain management over the study period. Furthermore, in the course of the research it became clear that the FDRP has had impacts on policy and practice relating to the protection of significant natural features such as wetlands. However, it also became clear that it is very difficult to establish the *specific* contribution of the program to increased concern for fragmentation of wetlands by political boundaries, public support for watershed functions, protection of environmentally sensitive areas and storm water management design standards. The next section addresses the difficulties, and provides suggestions for further research that uses the proposed methodology.

5. IMPLICATIONS FOR FUTURE FLOOD DAMAGE REDUCTION STUDIES

The purpose in this section is twofold. First, comments are offered relating to each of the program interventions and criteria used in the pilot study. Second, general observations are drawn regarding the application and utility of the proposed methodology, and challenges associated with comparative floodplain evaluation research.

5.1 Program Interventions

5.1.1 Floodplain Mapping

An important challenge in applying the proposed methodology for this program intervention is determining the extent to which floodplain mapping under the pertinent national program contributed to the recognition, delineation, and management of wetlands and other natural areas under conditions of divided jurisdiction. The pilot study demonstrates the difficulty of determining the reasons for outcomes. In other words, while it appears that there has been more attention to natural areas and functions during the past decades in the municipalities studied, it was not possible to determine the extent to which this increased attention is due to the FDRP. For example, while the Town of Caledon's 1997 official plan contains explicit reference to the protection, maintenance and enhancement of ecosystems, including watersheds, no indication is provided of why this theme was included in the plan. A parallel investigation by Wojtanowski (1997), which aimed to identify and assess additional or associated benefits and costs of the program in a range of areas, including protection of natural areas, underscores the challenge. She discovered that municipal and conservation authority officials generally were unable to determine the relative contribution of related initiatives. For example, changes in land use planning at the local level have been fostered by the FDRP as well as by the provincial government's floodplain planning policy statement (Ministry of Natural Resources and Ministry of Municipal Affairs, 1988) and wetland policy statement (Ministry of Natural Resources, 1992). In turn, these policy initiatives are reflective of a growing concern in Canada that urban and regional planning effectively incorporate environmental concerns. The challenge of being able to attribute specific changes to specific policies and programs is endemic in evaluation research.

The specific criterion for this program intervention is "artificial fragmentation of watersheds by political boundaries". While this may be a significant problem in some jurisdictions, it could be more appropriate in other settings to explicitly assess the effectiveness of collaborative mechanisms. For instance, as was evident in this study, Ontario's conservation authorities provide an institutional mechanism to overcome political fragmentation. Other jurisdictions may employ administrative, legal, or procedural instruments to facilitate watershed-based floodplain management programs, with varying success.

5.1.2 Public Education, Information and Awareness

The key concern here is the extent to which the floodplain management program has contributed to public support for watershed functions. In the context of the FDRP, did a municipality's participation in the program, especially in the mapping phase, contribute to greater awareness, support, or knowledge among citizens? As in the case of fragmentation of natural areas, it is almost impossible to determine how much of past and current awareness and support for watershed functions derives from the FDRP relative to other programs and considerations.

There also is a need to clarify terminology in relation to this intervention. Public information, education and awareness refer to three different aspects of knowledge. It is unclear how the measures proposed by Newton *et al.* (1996) capture these aspects. The work by Handmer (1980) may provide initial thoughts on how information, education and awareness may be more rigorously assessed. For instance, content analysis of local newspapers could provide insight into the occupancy, economic and natural functions values of floodplain management efforts.

5.1.3 Regulation of Land Use

In this pilot study, an effort was made to gather pertinent data from existing studies. The problem encountered was that these studies identify the proportion of environmentally sensitive areas (ESAs) inside and outside of designated floodplains. Data for the area of floodplains zoned for natural uses, and the length of protected streams, can be acquired easily if the appropriate features exist in digital form. In this case, a simple overlay analysis will provide the pertinent data. Various municipalities and conservation authorities may already have digital spatial databases.

What such an analysis will not establish is the link between the FDRP and the size of areas protected. Even if comparisons at ten year intervals are possible, and if they show an increase in the size of areas protected before and after floodplain mapping, only inferences may be possible. Additionally, a serious problem for a temporal analysis is the fact that municipalities and conservation authorities may not keep "layers" for previous years. In other words, their spatial databases may contain only current information. If this proves to be true, then researchers will have to acquire old maps and add them to an existing spatial database. This can be a costly and time-consuming effort. Finally, maps produced at different scales could pose analytical problems related to accuracy.

5.1.4 Performance Standards for Buildings

The "number of communities with development design standards for stormwater management" was identified as a possible criterion (Newton *et al.*, 1996). The usefulness of this measure is uncertain because over time, community boundaries can change due to amalgamation and merges. In this scenario, fewer communities would not necessarily reflect poorer performance. In addition, the tiered system of municipal planning in Ontario suggests that it is more important that regional governments establish effective policies for local governments to follow.

In this regard, it is more appropriate to assess the effectiveness of stormwater management systems according to the natural, economic and occupancy criteria noted by Newton *et al.* (1996). If applied to the City of Mississauga, this type of research effort would evaluate 22 facilities located there. However, 21 of these facilities are located outside designated floodplain areas of the Credit River.

A second performance standard pertained to site alterations. Although these are not a major part of FDRP, it is understood that areas designated as flood-prone in municipal planning documents "must have regard for" the 1988 Provincial Floodplain Planning Policy Statement. Previous research efforts have examined the implementation of these policies in the Credit and Upper Thames River watersheds (Shrubsole *et al.* 1995; 1997).

5.1.5 Relocation of Buildings

Air photo interpretation combined with title searches in the municipal Land Registry Office could be used to derive the year in which changes in ownership occurred for any land in floodplains. It would then be possible to identify and measure the size of any lands returned to public ownership. This would be a time- and labour-intensive undertaking, because structures on air photos would have to be identified and tied to specific property records.

The use of building permits is complicated by the fact that interviews indicated that most municipalities only store recent applications for building permits. For example, the Town of Orangeville only keeps complete files for the last 10 years.

Conceptual and definitional challenges are associated with measuring "acreage returned to natural function". In this instance, changing the program intervention title to "Floodplain Land Acquisition" from "Relocation of Buildings", as well as changing the focus of the research questions under "natural functions" to reflect land title transfers to public agencies or NGOs, might be appropriate.

5.1.6 Disaster Relief

Disaster relief is derived from the provincial and federal governments according to a well-defined formula and protocol (Andrews 1993). While no significant floods have occurred in the municipalities considered in this study since the initiation of the FDRP, major flooding events have occurred in the past three years in other parts of Canada (southern Alberta in 1995; the Saguenay Region of Quebec in 1996, and the Red River Valley in Manitoba in 1997). In each of these cases, the scale of the disaster has been such that the emphasis has been overwhelmingly on reconstruction. Further study may be warranted of the extent to which opportunities have been pursued in these dramatic cases to protect natural areas by *not* reconstructing in the floodplain.

5.2 General Observations

The pilot study highlighted some general concerns and issues regarding the use of the proposed methodology. These are summarized here.

5.2.1 The Counting Problem

Many of the measures related to the criteria rely on "counting" relevant items. While necessary and valuable, the underlying assumption is that more (or in some instances less) of an occurrence over time denotes "success". Since this is a narrow definition, it is appropriate to consider what mix of the measures identified by Newton *et al.* (1996) measure success. Additionally, it may be appropriate to broaden the measures of success. The measures often refer to performance outcomes. Little reference is provided to process and to other criteria such as equity, efficiency and adequacy.

5.2.2. Content Analysis

Another kind of counting problem relates to the content analysis approach used in this pilot study. It was difficult to draw meaningful conclusions from the frequency of occurrence of statements. While the presence of pertinent statements can be measured in documents, only careful analysis of the statements themselves can give any insight into the relationship between floodplain management and natural area protection in municipal official plans and other documents.

This level of analysis was not conducted in the pilot study, but it should be part of any further research using this approach. This is illustrated under the natural functions criteria, program intervention "Regulation of land use zoning", and the criterion "Natural use zoning in the community". The important concern is not how many times a municipal official plan mentions the term "natural use zoning", but whether or not the presence of that statement is due to the involvement of municipalities in the FDRP. This can be determined only through follow-up interviews that explore why particular statements were included. Additionally, this kind of analysis must be linked with a parallel investigation of actual practices. For example, it is important to discover the extent to which *stated* objectives are translated into *action*.

5.2.3 Definition of "Community"

While the term "community" is used throughout the proposal, it is unclear whether this refers to the same geographic area over time, or a changing administratively defined area. It is also appropriate to consider the differences used to define the term by different jurisdictions. For instance, in Canada, the whole community (in size and population) is counted as lying in flood-prone areas. This contrasts the approach in the United States that counts communities on the basis of residents who purchase flood insurance (Newton *et al.*, 1996).

Another problem with the concept of communities was highlighted in section 4.1.4. There it was noted that some municipalities treat hamlets and rural clusters as "communities" for planning purposes, while others consider the entire municipality to be one "community". Further research using the proposed methodology must clarify whether "community" means municipality, or whether it has a broader meaning.

5.2.4 Comparison of Institutional Arrangements

In comparing the FDRP to the NFIP, researchers must be sensitive to the significant differences in the institutional arrangements for floodplain management both within each country as well as between them. For instance, the U.S. *Flood Insurance Act* has provisions for financial and technical assistance to purchase flood-damaged buildings. In Ontario, this intervention would be the responsibility of conservation authorities and would not receive funds through FDRP. Other provinces do not have similar agencies. These circumstances suggest that researchers may be advised to assess the comparative effectiveness of an intervention rather than focus on the narrowly defined actions contained in FDRP and NFIP.

An additional complication is that institutional arrangements for floodplain management within each nation vary widely. For example, in Canada, it is the provincial governments that are principally responsible for implementing floodplain management initiatives. The role of the federal government has been to provide oversight, consistency, funding, and a leadership role. This role appeared to be necessary in 1975 when the FDRP was established, because each of the provinces was at a different stage. Some provinces, such as Ontario and Alberta, already had floodplain management initiatives, while others, such as New Brunswick, had not yet addressed the issue (de Loë and Mitchell, 1995). The situation in 1997 is not vastly different, in that the various provinces still have different capacities and institutional arrangements. Any Canada-U.S. comparison must take account of the differences in provincial (and U.S. state) floodplain management institutional arrangements.

5.2.5 The Challenge of a Longitudinal Analysis

Researchers will also have to balance the ideal situation of comparing activities for the same time periods. As the availability of municipal official plans in the Credit River watershed illustrates, it is unlikely that a comparison of all activities for 1970, 1980, 1990, and 2000 is feasible.

A significantly greater challenge for a longitudinal analysis is highlighted by the work conducted by Wojtanowski (1997). In her research aiming to identify and assess additional benefits and costs of the FDRP, she discovered that retirements and downsizing in the provincial and federal governments have resulted in a loss of key people with an awareness and understanding of the evolution of floodplain management in Ontario. This is a serious problem, because many of the most difficult questions posed in the proposed methodology may be answerable only by interviewing people who were active in floodplain management decades ago, and who now may have retired or otherwise moved on.

6. CONCLUSION

Evaluations of the impacts of resource management programs are difficult. The challenge addressed by the proposed floodplain management evaluation methodology evaluated in this research is greater than most.

- Floodplain management in Canada essentially is a provincial responsibility. Therefore, the federal government's role essentially has been one of providing leadership and consistency. Any cross-national comparison must take into account significant differences in provincial delivery of floodplain management under the FDRP.
- Since the inception of the FDRP in 1975, many important parallel initiatives have been pursued that relate to the program interventions measured by the proposed methodology. In the case of Ontario alone, the protection of wetlands and other important natural areas in floodplains has occurred under numerous initiatives, of which the FDRP is only one. This means that measuring the specific contribution of the FDRP will be extremely difficult.

In addition to these conceptual considerations, operational issues exist which should be resolved prior to further use of the proposed methodology. For example, these relate to:

- Definition of "community" and municipality".
- Appropriateness of criteria such as "artificial fragmentation of watersheds".
- Meaning of terms such as public "information", "education" and "awareness".
- Acquiring data for the size and extent of protected areas over time.
- Limitations of building permit data.

Nevertheless, this pilot study suggests that refinement of the Newton *et al.* (1996) and Montz *et al.* (No Date) methodology is warranted and feasible, and that its application to cross national situations is worthwhile.

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FLOOD DAMAGE REDUCTION PROGRAM IN QUÉBEC
CASE STUDY OF THE CHAUDIÈRE RIVER

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ABSTRACT

This study presents the evolution of the agreements between the Canada and Québec governments on flood damage reduction. In Québec, the implementation of a regulation about building in floodplains came about 1983-1984. Today, this regulation takes the form of a policy called "Policy of shores, littoral and floodplain protection". Municipalities must adopt rules that concur with the principles of this policy.

The Chaudière River has been selected to analyze urban development, ever since the application of building rules in flood-risk areas. Despite the ban on building in the strong current zone (0-20 year zone), many buildings, essentially residential, have been erected in this zone. These new constructions generally account for a low percentage of the total property value in the 0-100 year flooding area. These new buildings are legal, because they are connected to a water and sewage network that existed prior to the official floodplain regulation.

Flood damage along the Chaudière River will tend to increase for two reasons. Firstly, while respecting the policy mentioned above, sites are still available in floodplains for future development. Secondly, no structural works have been erected in view of the fact they are only marginally profitable from an economic point of view.

ACKNOWLEDGMENTS

This study was made possible because of the invaluable collaboration of many persons from different sectors. I wish to sincerely thank them for their receptiveness and collaboration. Those people are: the staff of the six municipalities concerned by the study, the staff of Nouvelle-Beauce, Robert-Cliche and Beauce-Sartigan RCMs and employees of the Environment and Wildlife Department and Public Safety Department.

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1. INTRODUCTION

Floods are natural phenomena that always have perturbed the social and economical activities of populations located near waterways. The province of Québec is very much concerned by this phenomenon, given its numerous rivers. As a matter of fact, during the 1970 to 1988 period, Québec received 36% of the federal and provincial flood victims assistance [11].

The mapping of risk zones has been the cornerstone of the Canada-Québec agreement on flood damage reduction [11]. As mapping is futile if it is not used efficiently, it is necessary to make an evaluation of its use. Thus, the aim of this study is to look to what extend this program has been implemented and, accordingly, to describe the evolution of the program since 1976.

This aim had been agreed to in April 1997 by the working group on the flood damage reduction program. The committee has been created by the Environmental Adaptation Research Group, Environment Canada, at the University of Toronto and the Senior Scientific Advisor of Emergency Preparedness Canada. Two other studies have also been initiated this year for Ontario and Manitoba.

This document includes a summary of the Canada-Québec agreements and of the Québec policies resulting those agreements. Then, in order to analyze the program's effectiveness, an urban development study of the Chaudière river basin has been undertaken. The Chaudière River, located on the south shore of the St. Lawrence, has been selected for this analysis because it has been the cause of many past floods. Also, in this report, the damages from historical floods have been examined to establish how their characteristics have changed or evolved over time. Conclusions on the most relevant issues are presented at the end of the document.

2. AGREEMENTS BETWEEN THE CANADIAN AND QUÉBEC GOVERNMENTS

The federal government established a program in 1976 which aimed to reduce flood damages in Canada. In Québec, this program has been established by the signature of a Canada-Québec agreement and has been modified twice. These agreements are:

1976	A federal-provincial agreement on flood risk mapping applied to flood damage reduction [2].
1987	A Canada-Québec agreement on mapping and floodplain protection [3].
1994	A Canada-Québec agreement on mapping and floodplain protection and to sustainable water resources development [4].

2.1 Objects of agreements

The 1976 agreement includes a flood damage reduction policy and an agreement on flood risk mapping. Under this agreement, both levels of government, through their departments and agencies, undertake to:

- avoid building or in any way subsidize the building of structures in strong current areas. In the weak current area, these same agencies can only allow the building of or provide financial assistance for structures that meet effective floodproofing standards;
- encourage municipal authorities to impose restrictions, as required, to prohibit or make subject to floodproofing measures any future structures located in designated flood-risk areas;
- make ineligible for disaster assistance any construction undertaken after the official designation of the flood-risk area.

The 1987 agreement goes on to identify flood-risk zones and their geographical area. Also, it aims to establish jointly an intervention policy to reduce damages within each government's field of jurisdiction.

The 1994 agreement has the same main objectives as the 1987 agreement, with the exception of a new item. This new item is about special studies on sustainable water resources development and, more specifically, on its management at the basin scale. In March 1997, the agreement ended regarding flood area identification, and will expire in March 2002 with the implementation of the intervention policy.

2.2 Differences between 1987 and 1994 agreements

First, the construction categories exempted from the intervention policy regarding flood areas are the same in both agreements. For example, residential construction is permitted in a flood area if it is located along a street with a water and/or sewage network. The differences lie in structures eligible for exemption. In the 1994 agreement, the following categories have been added:

- *Residential extensions*

Residential extensions are permitted (in the 1987 agreement, only commercial and industrial extensions were eligible for exemption).

- *Construction on an island*

Commercial, industrial or residential buildings can be erected on an island if certain conditions are met. For example, the island is considered adjacent to a street if it is joined to it by an existing bridge.

- *Embankment*

A structure located on a lot totally protected from a 100-year flood (protected without an embankment) is eligible for exemption. A site legally filled above the 100-year height level, is also eligible for exemption. But the exemption will only be given after the municipality has modified its regulation to prohibit any subsequent embankment works. Finally, earth moving works in recreational areas have may be be allowed in the strong flow zone (0-20 year flood).

2.3 Budgetary statement

The cumulative expenditures since the signing of the first agreement of October 1976 to March 1996 is $13,213,558 [17]. The financial contribution of the federal government has been $6,523,481. In Québec, nearly 250 municipalities have been involved in this program, contributing to the production of 95 maps with a 1:10,000 scale, 92 maps at 1:5,000 and 846 maps at 1:2,000.

For the Chaudière river basin, 19 municipalities have benefited from the mapping program, with expenditures rising to $290 203. The number of maps produced were: 8 (1:10,000), 6 (1:5,000) and 31 (1:2,000).

2.4 Exemptions

There were 54 exemptions authorized by the agreement implementation committee from 1976 to March 1996 for the province of Québec. From this number, 15 were for the Beauce region (Chaudière river region) [17]. These exemptions were mainly for the construction of water treatment plants, building expansion and road extensions. The following is a list of those exemptions:

Table 2.1: Exemptions from the Canada-Quebec agreement for the Chaudière Region

Municipalities	Exemption	Year
Sainte-Marie	Drinking water well	1984
	Continuation of Larochelle boulevard	1988
	Extension of Bonneville Industry	1988
	Extension of Bonneville Industry	1989
	Extension of Bonneville Industry	1992
Beauceville	Waste water treatment plant	1984
	Extension of Saint-Lambert Avenue	1988
Notre-Dame-des-Pins	Waste water treatment plant	1984
Saint-Joseph	Waste water treatment plant	1984
Scott	Extension of a convenience store	1988
	Replacement of a bridge	1994
Saint-Georges	Bypass of road 204	1988
	Road 173	1990
Vallée-Jonction	Extension of a Credit Union	1988
	Construction of a building	1991

3. EVOLUTION OF POLICIES IN QUÉBEC

3.1 Development and Town Planning Act

In 1979, the Québec government adopted the Development and Town Planning Act, including the creation of Regional County Municipalities (RCMs) [12]. These regional entities manage their territory with regards to:

- major territory allocations and orientations;
- town development perimeters;
- areas subjected to public security constraints or environmental protection zones;
- ground transportation organization;
- regional equipments and infrastructures.

The RCMs had to adopt their territorial development plan in the seven years following the adoption of the law. Meanwhile, the RCMs had to adopt provisional control regulations (PCR) which included floodplain management standards. Those standards had to be based on the flood-risk maps (established in 1979 for the Chaudière River) from the Canada-Québec agreement. These standards had to be approved by the Minister for Municipal Affairs. It should be noted that for some RCMs, the control regulations have been succinctly amended and modified. During those modifications, all construction projects submitted to the amended PCRs, were suspended. Table 3.1 shows the years of implementation of the PCRs and of the development plans for the three Chaudière River RCMs [20, 21 and 22].

Table 3.1: Chaudière River RCMs

RCM	Creation of RCM	Implementation of PCR	Implementation of development plan
Nouvelle-Beauce	1981	1983	1990
Robert-Cliche	1981	1983	1988
Beauce-Sartigan	1982	1984	1988

It should be noted that the establishment of the development plans began with the implementation of the PCRs.

In the period from the establishment of flood-risk maps until the implementation of the PCRs (that is to say from 1979 to 1983), the Québec government identified and recommended, without any legal obligation that municipalities not build in flood prone areas.

Since 1993, article 5 of the Development and Town Planning Act stipulates that RCMs will have to establish flood-risk zones and not simply identify them like before [19]. Now, all types of floods have to be considered, including ice-jam floods. It should be emphasized that the Canada-Québec agreement deals only with open flow floods and consequently does not include the mapping of those other flood types. Many municipalities along the Chaudière River have often been subjected to ice-jam flooding, along with the communities of Beauceville and Saint-Joseph. Those types of floods caused more damage than open water conditions floods. In Beauceville, an ice-jam flood is equivalent to an open flow flood with a 200-year return period [8]. The mapping of the flood areas not dealt with under the Canada-Québec agreement is now being carried out and is almost complete for the Beauce-Sartigan RCM.

3.2 Québec government policies

Following the floodplain agreements, in 1987, the Québec government established a policy called "Policy of shores, littoral and floodplain protection" [13]. The government preferred a policy over a provincial regulation, so as not to infringe upon the jurisdiction of municipalities in territorial planning matters.

Implementation

The Environment and Wildlife Department is responsible for the implementation of the policy and for its coordination. But, in accordance with RCM development plans, it is the municipalities which adopt the regulations allowing the implementation of the policy. Municipalities also look at the application of the policy in accordance with the Development and Town Planning Act. This Act allows for the Environment and Wildlife Minister to ask municipalities to modify their regulations if they are contrary to government policy or do not lead to an appropriate protection of shores and floodplains, when considering site conditions.

Differences between 1987 and 1996 policies

The policy of 1987 was modified in 1991, and more recently in 1996 [14], so as to take into account site characteristics. The main differences between the 1987 and 1996 policies are the following:

- the addition of some exceptions in the waterside zone, which take into account existing situations and rights; this allows some construction or even extensions to existing buildings in particular circumstances.

- the addition of a particular section on floodplain protection, notably by the integration in the policy of Annex E and F from the Canada-Québec agreement. Those annexes contain constructions not covered by the regulation, and construction eligible for exemption.

- the addition of a mechanism which allows a RCM to propose a shoreline management plan when its development plan is being reviewed. The aim of this measure is to deal with special situations, taking into account site quality and degree of modification. In this case, the strict application of policy rules is not always appropriate. It may be necessary to adopt measures different from those included in the policy while providing adequate protection of those shoreline sites.

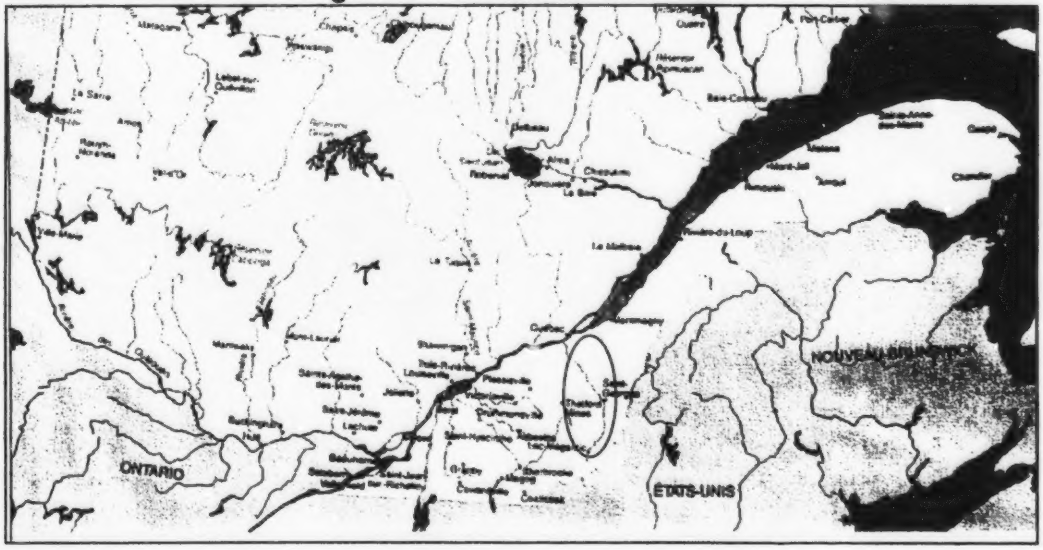
4. PROBLEMS CHARACTERISTIC TO THE CHAUDIÈRE RIVER

4.1 Basin description

The hydrological basin of the Chaudière River is located on the south shore of the St. Lawrence River (Figure 4.1) and covers a 6,682 km^2 area [23]. The river, entirely located within the province of Québec, is 210 km long and has three sections [15]:

- the high-Chaudière includes the area between Lac Mégantic and the southern part of the town of Saint-Georges and makes its way through forested land;
- the mid-Chaudière extends from Saint-Georges to Sainte-Marie; most of the population and most industries are located along this section of the river;
- the low-Chaudière includes the territory between Sainte-Marie and its confluence with the St. Lawrence river; this region is mainly agricultural.

Figure 4.1: Chaudière River basin



4.2 Flood causes

Flooding of the Chaudière River cannot be dissociated from its history. This flooding is natural but humans have contributed to its increased occurrence. The main problems resulting from human activity are the following:

1) road development which has doubled the drainage network since 1950;
2) bridge approaches;
3) gravel pit operations in the river bed;
4) agricultural drainage;
5) forestry.

Natural causes
The main reasons for floods are the following:

1) longitudinal profile
The mid-Chaudière sector has a low slope compared to the downstream and upstream sections. The river's mean slope in this area is only 1%. Consequently, this section cannot absorb the overflow during a flood.

2) high rate of ice accumulation
The high rate of ice accumulation on the Chaudière River comes from a combination of low flow and significant bed dimensions. Then, ice-jams form easily.

3) low absorption capacity of minor bed
The difference between the water level and the banks is only 1.5 metres. This small difference often leads to overflows.

4) presence of numerous tributaries
The mouth of the main tributaries are located in the mid Chaudière section where the slope of the river is very slight. The main tributaries are the Linière, Famine and Saint-Victor Rivers.

5) natural obstacles
Firstly, the Chaudière River has narrow sections, steps and rocky outcrops. The "rapides du diable" (rapids), upstream of the city Saint-Georges, are a good example. Secondly, the Chaudière river has many islands. There are fifteen islands in the studied section between Scott and Saint-Georges. Thirdly, lateral deltas at tributary mouths disturb ice flow. The Saint-Victor River delta is the main culprit. Finally, the Chaudière River is especially winding in nature, thus resulting in the presence of friction zones for ice. The section located just upstream of Saint-Georges is a frequent ice-jam zone.

4.3 History of Chaudière River floods

The maximum flow rate was recorded in 1991 at 2140 m^3/s (Saint-Lambert station) [1]. Comparatively, the weakest flow has been 3 m^3/s (at the same station), thus illustrating the large intraannual variability that characterizes the flow volume of the mid-Chaudière River.

The 20-year period from 1971 to 1991 account for 10 of the 19 registered floods from 1915 to 1991. The threshold value for flood conditions is 1300 m^3/s, observed at the Saint-Lambert station. Moreover, the 20-year return period flow (1600 m^3/s) now occurs every 7 years. This means a flood frequency increase for the last 20-year period [8].

4.4 Costs of damages and solutions

The mean annual damage cost for municipalities of the Beauce region touched by open water floods would stand between $1.2 and 2.5M, while it is estimated at $1M for those caused by ice jams (Beauceville area).

The committee for the Chaudière River flood problems, which was created in 1991 after the major floods of 1987 and 1991, had funded a major study carried out by Tecsult to find possible solutions to flooding.

The study shows that to eliminate flood risks, it would be necessary to increase by 25% the main channel flow capacity or to reduce the peak flow in the same proportions. The increase in flow capacity means that the river bed must be dug over a long distance, resulting in large costs and considerable environmental impacts. Reducing the peak flow means that one has to hold more than a hundred million cubic metres of water, which has almost prohibitive costs ($100M) [8].

Finally, no structural work has been done since this study, since the suggested solutions were very costly and only marginally profitable on a long-term basis. At present, partial solutions to flood problems are ice-breaking operations in the spring to avoid ice-jams, and the use of a floodplain protection policy that prohibits construction works in the strong current zone (0-20 year zone).

4.5 Territory in floodplain

In order to establish the potential of municipality development in the floodplain, the percentage of the territory located in the risk zone has been determined (Table 4.1). Those data, obtained with a hand-held instrument, are approximate and rounded to the nearest integer. Nevertheless, they indicate that the municipalities where floodplain development could most likely occur are Vallée-Jonction and Saint-Joseph.

As a result of the floodplain protection policy, the Nouvelle-Beauce RCM has established an "urban consolidation perimeter" in the 0-20 year flood zone. This perimeter limits new construction projects to a territory served by a water and/or sewage network which was in place prior to adoption of the policy. For example, at Vallée-Jonction, the area enclosed in the consolidation perimeter in the floodplain is reduced to 15% instead of 35%.

Table 4.1: Territory and number of buildings in floodplain

RCM	Municipalities	% of territory in floodplain	Number of buildings in floodplain
Nouvelle-Beauce	Scott/Taschereau-Fortier	15	50
	Sainte-Marie (v)	15	400
	Vallée-Jonction	35	40
Robert-Cliche	Saint-Joseph (v)	30	35
	Beauceville	5	35
Beauce-Sartigan	Saint-Georges (v)	5	30

* The letter (v) means that the area has been established only for the city and not for the parish having the same name. The percentage would be lower if the parish area were considered because, it includes a large unurbanized territory and is used for agricultural activities.

It should be noted that the number of buildings was determined with the 1979 flood maps for the risk zone, updated in 1994 by aerial photographs taken by Tecsult [8]. Also, those approximate figures include all types of buildings (residential, commercial, industrial and institutional). Consequently, potential flood damage can be very high because of the presence of industrial or commercial establishments.

5. MANAGEMENT OF CHAUDIÈRE RIVER FLOODPLAIN

Different agencies manage or study the Chaudière River's floodplain. Besides the various departments involved, a number of ad hoc committees have been formed over time to analyze flood issues.

5.1 Chaudière River basin committee (COBARIC in French)

The management of water in the province of Québec is shared between many agencies from federal, provincial and municipal levels of government that have their own regulation. It is in this context that COBARIC has been created in 1994. This committee has about 20 members from the municipal, agricultural, forestry, industrial, tourism, health and environment sectors. Its mandate is to propose an integrated water management approach adapted to the Québec context to the Environment and Wildlife Minister.

The committee had to determine the type of organization that could be created, the type of power it would have as well its modes of operation and financing. The conclusions had to be based on the various problems of the Chaudière River. In 1996, COBARIC published a report containing the leading principles necessary to a real integrated management of Québec water resources [23]. One of the basic principles was that the hydrological basin of a river constitutes the best natural unit for water management.

5.2 Public Safety Department

Following the exceptional floods of 1991, the Public Safety Minister asked Tecsult to undertake a modelling exercise of the Chaudière River [5, 6, 7 and 8]. This study also included an evaluation of possible solutions to flooding in the area.

The Public Safety Department provides technical support to municipalities affected by flooding. An example of the work is exemplified by a 1992 report on measures to take when spring ice-jams occur [18].

5.3 Environment and Wildlife Department

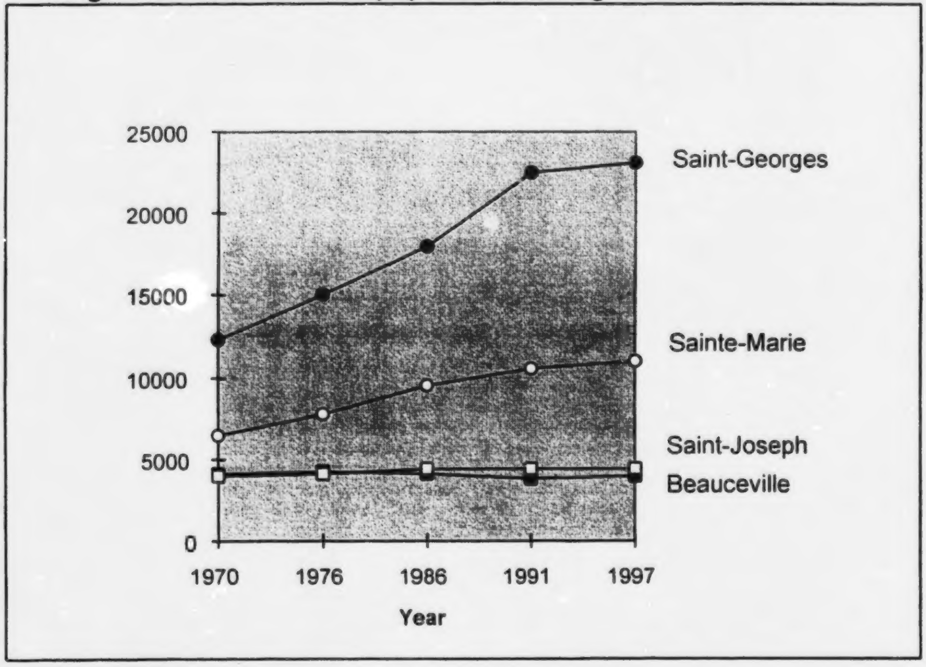
This Department ensures that the policy of shores, littoral and floodplain protection is applied (see section 3.2). It also receives exemption requests and submits them to the agreement committee. The Department works in full cooperation with the Public Safety Department, so as to provide technical support to municipalities for the interpretation and application of the policy mentioned above.

6. EVOLUTION OF URBAN DEVELOPMENT

6.1 Population

The total population of the Chaudière River basin was in 1979, at the time of the first agreement, about 50,000 [9]. This number has since tripled and stands now at approximately 150,000 [23]. The evolution in populations for the four major municipalities along the Chaudière River is shown in Figure 6.1. Saint-Georges and Sainte-Marie are the two towns that have had the most significant increase of their number of citizens. The population of Saint-Joseph and Beauceville are steady or have even dropped. Vallée-Jonction and Scott follow this latter trend. It is still to be established if this increase has occurred within the floodplain. This point is discussed in the following paragraphs.

Figure 6.1: Evolution of populations along the Chaudière River



6.2 New construction

To study the application of the floodplain protection policy, the number of new buildings has been compiled for the six municipalities located in the flooding section of the Chaudière River. The types of buildings have been divided into four categories and their corresponding cumulative property values are shown in Table 6.1. Firstly, the streets in the floodplains were located using the flood-risk maps established within the context of the Canada-Québec agreement. Then, with civic numbers noted in the field, the construction year of buildings was found from the municipal records. Finally, the value of properties built since 1979 was recorded. The year 1979 corresponds to the end of the mapping process of the Chaudière River and to the adoption of the Development and Town planning Act (section 3.1).

Some difficulties were encountered regarding the determination of locations of properties and buildings. Since the 0-100 year flood zone is not clearly established on the maps of all municipalities, it often had to be approximated. Also, there is no interpretation rule to establish if land is located inside or outside a floodplain area according to its size within this area. The Beauce-Sartigan RCM is the only one to include a clause in its development plan in this regard. This clause is the following: when 50% or more of land is subjected to the most stringent standards, these apply independently to that part of the land where a new building is to be erected. In this study, this percentage has been used except for a few buildings that were observed to be in the floodplain, even if a small part of the lot was in the risk zone. Also, town planners and development managers from the RCMs were consulted in this regard.

Table 6.1: Property value of buildings in the 0-100 year floodplain (1979 to 1997)

Municipalities	Houses	Apartment buildings	Industries Commercial enterprises Institutions	Total ($) (1996 property value)
Scott/Tasch.-F.	1 184 100	---	---	1 184 100
0-20 year	0 %	---	---	
Sainte-Marie	198 100	1 946 500	3 798 300	5 942 900
0-20 year	72 %	85 %	44 %	
Vallée Jonction	781 300	277 600	---	1 058 900
0-20 year	48 %	53 %	---	
Saint-Joseph	785 900	---	107 500	893 400+
0-20 year	37 %	---	0 %	
Beauceville	397 100	---	626 700	1 023 800
0-20 year	100 %	---	37 %	
Saint-Georges	210 000	---	7 941 100	8 151 100
0-20 year	100 %	---	100 %	
TOTAL ($)	3 556 500	2 224 100	12 292 100	18 254 200

Note: Table 6.1 percentages are the ratios between new buildings in the 0-20 year zone and the total number of new buildings (0-100 year zone).

Table 6.1 indicates that new buildings have been erected in the strong current zone (0-20 year), despite the fact it is forbidden to build in such areas. However, all of these buildings are legal because they are connected to a water and/or sewage network laid prior to adoption of the RCMs regulation resulting from the Canada-Québec agreement. New streets and utility networks were built at the end of the 1970s and at the beginning of 1980s.

Table 6.1 also shows that Sainte-Marie and Saint-Georges have the most significant development in the floodplain. It is necessary to underline the fact that those municipalities are the only ones with a growing population (Figure 6.1). But those cities have different building categories. In Sainte-Marie, we find mostly apartment buildings, while in Saint-Georges, most buildings are commercial. Among the latter, there is a grocery store worth more than $3M.

To estimate the magnitude of the development in the floodplain, data from Table 6.1 have been compared with the total value of buildings in the 0-100 year zone shown in Table 6.2. The ratios, in percentages, are included in Table 6.3. We can see that for an 18-year period (1979-1997), new construction represented a lower percentage of the total value in the floodplain (about 8.7% for the Chaudière River basin), without considering the exceptional case of Saint-Georges. This low percentage can be explained by the fact that the cities are old, having been founded in the 1800s. Old downtown areas near the river exemplify this. Consequently, there is not much room for new development.

The case of Saint-Georges is totally different. A commercial sector, made up of about ten establishments, has risen in the floodplain. This development is legal, since the street in question has been served by a public utilities network since 1979, just prior to the adoption of any floodplain regulation.

Scott and Saint-Joseph also show high development percentages (14.3% and 12.5%). But those towns have not shown an increase in population. Thus, there are no new residential or industrial properties.

Those property values will still increase in the next few years, but at a lower rate than for the last period. Some land is still available in the floodplain (where a public network exists). For example, in Sainte-Marie, 21 lots are still available for construction in the 20-100 year zone.

Table 6.2: Building value in the 0-100 year floodplain (1997 dollars) [8]

Municipality	Houses	Commercial enterprises	Industries	Institutions	Others	TOTAL
Scott/ T.-F.	6 447 711 (79)	662 661 (8)	92 397 (1)	864 689 (10)	191 228 (2)	8 258 686
Sainte-Marie	42 049 346 (47)	11 440 339 (13)	17 305 797 (19)	15 384 247 (17)	3 266 530 (4)	89 446 259
Vallée-Jonction	16 422 702 (70)	1 027 701 (4)	3 525 405 (15)	1 813 322 (8)	690 437 (3)	23 479 567
Saint-Joseph	3 988 284 (56)	1 413 260 (20)	1 386 966 (19)	356 876 (5)	--- ---	7 145 386
Beauceville	5 514 710 (31)	7 826 785 (43)	1 990 496 (11)	2 618 529 (15)	--- ---	17 950 520
Saint-Georges	--- ---	9 615 100 (76)	--- ---	3 069 800 (24)	--- ---	12 684 900
TOTAL	74 422 753 (47)	31 985 846 (20)	24 301 061 (15)	24 107 463 (15)	4 148 195 (3)	158 965 318

Notes (Table 6.2):

1) Values from Tecsult (1993) [5] have been adjusted to 1997 dolllars. Also, values for new buildings from 1994 to 1997 have been added to those of 1993. The report from Tecsult does not include property values for Saint-Georges.
2) Price index [10]: July 1997/1993 = 135.2/130.5
3) Numbers in brackets are percentages of total building value for the same municipality.

Table 6.3: Ratio of new property values (1979 to 1997) in floodplain to total value in the same zone

Municipality	Percentage (%)
Scott/ T.-F.	14.3
Sainte-Marie	6.6
Vallée-Jonction	4.5
Saint-Joseph	12.5
Beauceville	5.7
Saint-Georges	64.3

7. EVOLUTION OF DAMAGES

7.1 Value of disaster assistance payments

Figure 7.1 shows the indemnities paid by the Department of Civil Safety to the Beauce region for floods between 1974 and 1997. Indemnities are used for want of real damages that are not posted for old floods. The indemnities are compiled for each of the six municipalities of Table 7.1. Although they are significantly lower than the real damages, they are representative of the evolution of damages, because the compensation rate is fairly constant in time. This rate is of the order of 20% and covers only essential assets [16].

The most significant indemnities are for 1991 for a 30-year return period flood [8].

Figure 7.1: Indemnities for the Chaudière River basin

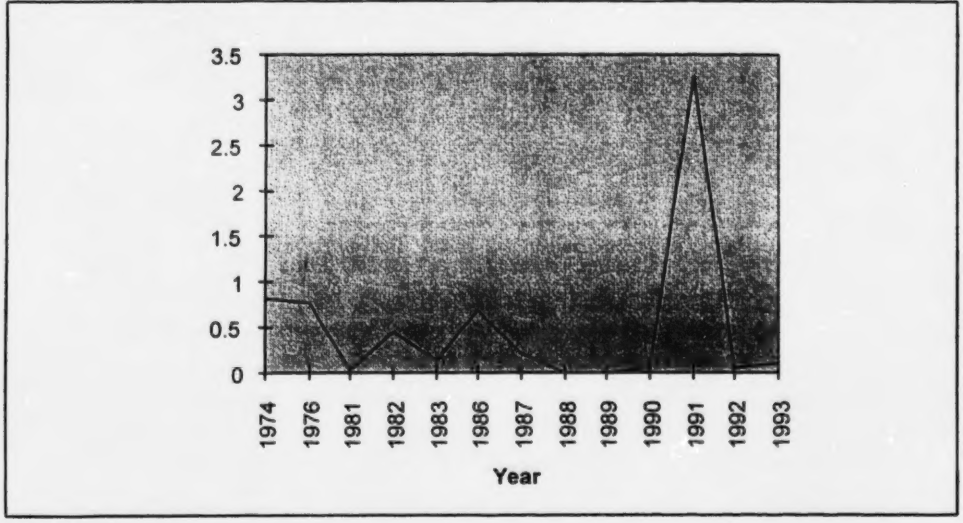


Table 7.1: Indemnities paid by the Department of Public Safety (1997 dollars) due to floods in Beauce (1974 to 1993) [8]

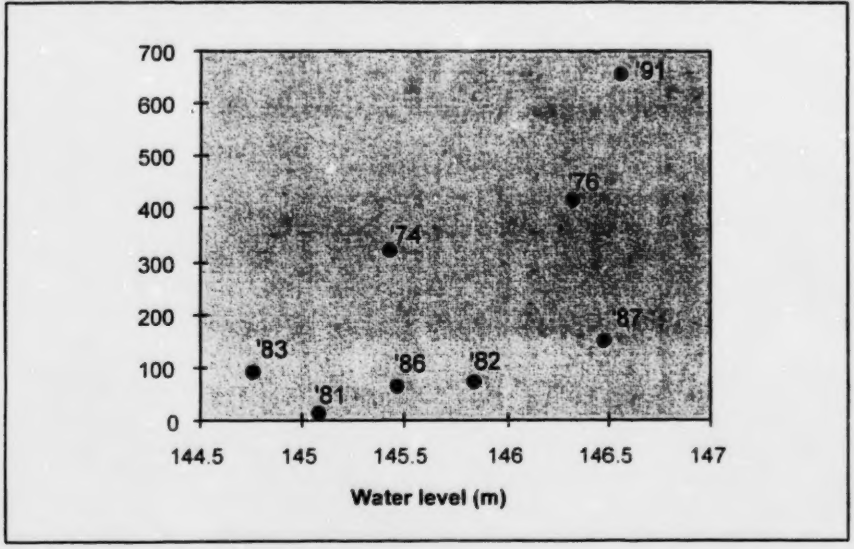
Year	Scott	Ste-Marie	Vallée-Jonction	St-Joseph	Beauceville	St-Georges
1974	---	320 159	68 010	122 910	215 349	101 894
1976	---	414 077	53 346	145 739	108 684	33 159
1981	---	13 486	1 552	8 593	---	---
1982	---	74 224	328 214	37 116	9 147	---
1983	---	90 099	---	44 548	---	---
1986	---	62 673	---	---	102 614	518 771
1987	---	147 493	49 780	22 896	---	---
1988	---	---	---	11 190	---	---
1989	---	---	2 893	13 787	---	---
1990	---	---	---	---	---	59 637
1991	56 153	655 466	82 756	---	2 448 999	---
1992	---	---	---	---	---	52 525
1993	---	---	---	---	103 755	---
TOTAL	56 153	1 777 677	586 550	406 778	2 884 793	713 461
Total for Beauce (most affected municipalities) = $6 425 412						

7.2 Aspects of study on the evolution of damages

Two aspects must be considered in the study of the evolution of damages. First, the increase in flood frequency should be studied. As discussed in section 4.3, the flood frequency of the Chaudière River is on the increase. This tendency is more critical when combined with the other limiting physical characteristics listed in section 4. Therefore, the ice-jams at Beauceville which create the most extensive damage will not be reduced.

A second aspect in the study of the evolution in flood damages is urban development. Consequently, a link has been established between indemnities and the water level during flooding. Figure 7.2 shows the water level reached at Sainte-Marie and indemnities paid to this municipality. The indemnities are four times higher in 1991 than in 1987 for a water level difference of only 8 centimeters. The irregularities are probably due to the fact that the rate of indemnities has changed over time, contrary to the supposed constant value of 20%. Consequently, it is not possible to quantify the evolution of damages. But, it is obvious that damages have increased as stated in section 6.

Figure 7.2: Indemnities paid in relation to water levels of floods in Sainte-Marie.



7.3 *Other factors explaining the evolution of damages*

During this study, other factors besides urban development were observed to be contributing to the increase in flood damage.

1) Buildings located in floodplains are restored more often and even rebuilt. Also, the downtown areas, established in all cases along the river, are revitalized. For example, some municipalities freeze taxes for owners who restore their buildings. These factors contribute to the rise in property value in the floodplain.

2) Many construction projects are eligible for exemptions. Some authorized exemptions are in downtown areas, where economical activities are significant. Therefore, industrial or commercial building extensions have economical impacts. Also, the relocation of buildings is not encouraged, since there is no financial assistance in this regard. In the three RCMs studied, only one industry has relocated. It is a bottling company located in Vallée-Jonction in the Nouvelle-Beauce RCM, with a property value of $382,000.

8. CONCLUSION

Floodplain protection policies have been relaxed since the first Canada-Québec agreement. Exemptions to the policy are possible; building extensions and some embankment work are permitted. Those changes also aim at a better adaptation of the policy to different sites.

Despite the fact that the policy is less stringent about building projects, Chaudière River floods are no less frequent. On the contrary, the river sediment accumulation near Beauceville and the fact that no new mitigative measures have been implemented suggest that floods will continue to cause significant damage.

Floodplains were developed and inhabited long before the establishment of any floodplain management policy. There is little room for new development in those high risk areas. The new buildings recorded in this study are legal, since they are connected to an existing water and/or sewage network that predates the agreements.

Finally, seeing that heavy construction measures are not economically feasible (section 4), the flood damage reduction program should be based on the strict application of its no construction and proofing rules.

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THE EFFECTIVENESS OF FLOOD DAMAGE REDUCTION MEASURES IN THE MONTREAL REGION

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ABSTRACT

The purpose of this study is to assess the effectiveness of two flood damage reduction measures—designation and dyking of floodplains. The study was carried out in four Quebec municipalities located on the shores of Lac des Deux-Montagnes and Rivière des Mille-Iles, namely Sainte-Marthe-sur-le-Lac, Saint-Eustache, Rosemère and Bois-des-Filion. Criteria for selecting the study areas were: area of the flood-risk zone, presence or absence of dykes, presence or absence of buildings, and availability of data. The study areas were selected with the help of flood risk maps of the Greater Montreal region. In each area, information on the number of buildings and their economic value was taken from the municipality's property assessment database. Trends in the occupance and value of floodplains were identified and compared. The results of the study show that, as in other regions of Canada, flood damage reduction measures based on designation and mapping of floodplains have had no impact on occupance, have failed to reduce flood damages, and have not even halted increases in such damages.

1. INTRODUCTION

Large-scale natural phenomena such as earthquakes, hurricanes, storms and floods are commonplace. When they affect inhabited areas, the impact is often substantial: consider tropical storm Mitch, the flooding in China in summer 1998, and closer to us, the January 1998 ice storm in Quebec and Ontario, the Red River flood in Manitoba in 1997, and the torrential rains in the Saguenay River Valley in July 1996.

The rapid expansion of Canada's population during the 1950s and 1960s gave rise to significant urban development, especially near water bodies (Newton *et al.* 1996). The result was increased exposure to flooding (Bouillon *et al.* 1999, Morris-Oswald *et al.* 1998, Roy 1997). There was a considerable increase in payments to people who had experienced damages (Bruce 1994, Morris-Oswald *et al.* 1998, Newton *et al.* 1996, Roy 1997). The need to limit losses and suffering became a priority, both in public opinion and for the various levels of government (Newton *et al.* 1996). There was a political will to act, and the result was the Federal Flood Damage Reduction Program, adopted in 1975. The program had three objectives: to reduce the risk of human suffering and loss of life; to reduce the cost of assisting those suffering damages; and to limit to a minimum the need to build impact mitigation structures such as dykes and dams. Under this program, a number of federal/provincial agreements were signed regarding measures to be taken to reduce damages (Government of Canada and Government of Quebec 1976).

Since a similar program had been set up in the United States at about the same time, scientists meeting at the trilateral conference on natural disasters in Merrickville, Ontario, suggested that research be undertaken to assess and compare the results of the two programs (Etkin 1995). The present study is part of this North-American research project.

The study aims to assess the effectiveness of two flood damage reduction measures, namely designation of floodplains and dyking. The agreement on mapping floodplains signed by the governments of Canada and Quebec in 1976 provided for designation of "flood-risk areas", their mapping, and public distribution of the maps. This gave public agencies the tools they needed to prevent the building of structures that would be vulnerable to flooding—or to end financial support for such construction; to encourage municipal authorities to impose restrictions on all construction in designated flood-risk areas; and to make ineligible for compensation any construction undertaken in an area after it had been officially designated. Development of utilities such as water/sewage, telecommunications and hydro/gas distribution systems was also restricted through subsequent policies and agreements. As a result, residential development on floodplains should have been minimal or non-existent after designation. This study asks the question: have the mapping and designation of floodplains made it possible to reduce flood damage by limiting the occupance of floodplains and reducing their economic value?

The other approach considered in this study is dyking. In some areas that were already heavily built-up at the time of designation, dykes were constructed to keep bodies of water from overflowing into the floodplain. The result may have been to create a sense of security among those wishing to settle in these areas; they may have come in greater numbers than would otherwise have been the case, and they may have built homes of greater value. If this is indeed what happened, then the potential for flood damage has probably increased. The study examines the question of whether dyking has affected the occupance and economic value of these so-called protected areas.

2. METHODOLOGY

2.1 Occupance and economic value of floodplains

Throughout history, lowlands and areas adjacent to bodies of water have been among the first places settled by new arrivals. Floodplains are very attractive to settlers because they are near water, very fertile and well irrigated. Humans have occupied such areas for a very long time. Occupance is reflected in the presence of residential, commercial and industrial buildings and in the use of lands for agriculture or forestry.

With occupance, an area's resources acquire an economic value. The more useful or desirable these resources are, the greater their value. The economic value of floodplains varies with people's interest in the resources they contain.

Aside from a few rare instances where there is significant erosion, 20-year or 100-year floods do little damage to soil or trees. However buildings and their contents may be severely affected. The present study is concerned only with buildings, as a manifestation of occupance. Occupance will be evaluated as the number of buildings in a given area, and economic value will be represented by the monetary value of these buildings.

2.2 Design of the study

The study is based on property assessments and on information from the maps produced through the Flood-Risk Mapping Program between May 1978 and September 1996. Trends were determined for occupance and economic value in each of the study areas, and these trends were then compared.

2.2.1 Criteria for selecting study areas

The study areas were selected using the following criteria. Designation had occurred far enough in the past for the public and officials to have responded. Structural mitigation measures had been taken to reduce flood damage. The area subject to flooding covered several thousand square metres, so that a representative sample of temporal and spatial trends could be obtained. There was strong urban development pressure in order to put to the test the Quebec Government's Protection Policy for Lakeshores, Riverbanks, Littoral Zones and Floodplains (Government of Quebec 1996). Finally, data of high quality had to be available.

Each study area had to contain a designated flood-risk zone and a designated no-flood-risk zone. The latter had to be adjacent to the former, and contain no commercial arterial roads. The flood-risk zones had to have specific features with regard to dykes and built-up portions: some had to have been dyked many years previously, others not; some had to have been for the most part built-up at the time of designation, others had to have been for the most part not built up. Thus there were four possible types of study area, having the features shown in Table 1.

Table 1: Features of potential study areas

Type of area	Flood-risk zone				No-flood-risk zone
	not dyked	dyked	not built up	built up	
1					
2					
3					
4					

2.2.2 Study areas selected

The Greater Montreal region has features which make it possible to meet the criteria. Flood-risk areas were designated over 20 years ago, which seems sufficient for officials to have made people aware of them and for the public to have adapted. The region also has large areas subject to flooding as well as very strong development pressure, especially in the northern and southern suburban belts. Finally, the region has dykes built some 20 years ago.

Study areas were selected, on the basis of the previously stated criteria, using flood-risk maps of the Greater Montreal region bearing numbers 31H12-100-0101, 31H12-100-0202 and 31H12-100-0302. To achieve homogeneity so that comparisons could be made, all the areas selected were in the region's northern suburban belt (information on which was also more readily available). A total of seven areas bordering Lac des Deux-Montagnes and Riviere des Mille-Iles were selected. Appendix 3 shows their geographical location. All seven had their flood-risk zones designated on 11 May 1978. Only one had had land withdrawn from the flood-risk zone. Table 2 shows the features of each of the study areas.

Table 2. Features of the selected study areas

Type of area	Name	Flood-risk zone					No-flood-risk zone
		not dyked	dyked	not built up	built up	with-drawal	
1	Deux-Montagnes						
	Boisbriand						
2	Saint-Eustache						
	Bois-des-Filion (not dyked)						
4	Ste-Marthe-sur-le-Lac						
	Rosemère						
	Bois-des-Filion (dyked)						

There are no type-3 areas because there are no areas around Montreal which are dyked but not built up. Dykes are only built to protect a built-up area having a certain economic value.

2.2.3 Accessibility of information

The municipalities differ in the structure of their property assessment data and the electronic form in which this data is available. Some have their own computer service departments, while others (Bois-des-Filion for example) use outside services. Each municipality uses its own database management program. Some data are directly accessible using *Microsoft Excel*, others are not. Thus for Saint-Eustache, files had to be manipulated extensively before the data could be extracted in *Excel* format. In the case of Rosemère, the file we received was incomplete and we had to conduct a search in their computer system to obtain information on year of construction. Finally, Deux-Montagnes did not have the information we needed in a computer form we could access. Computer files would have to have been created from data submitted on paper—unjustifiable extra work given the duration of the project. The problems we encountered suggest that property assessment data should be structured in a single electronic form (or compatible forms). A growing number of systems are using this information, and manipulating the data is very costly and tedious work. Political will is required to move things in a desirable direction.

Some municipalities wondered about the legality of providing information that included names of property owners. Quebec's Commission d'Accès à l'Information [access to information board] was consulted to determine the provisions of the legislation in this regard. The answer was that there was no problem as long the information was kept confidential.

2.3 Data on occupance and economic value

2.3.1 Data sources

A study of such large areas calls for detailed, reliable data that is readily accessible at low cost. The property assessment databases available from the municipalities meet all of these criteria. The 6 municipalities listed on Table 2 were approached and asked to provide the following information on each property in the study area(s) that lies within the municipality's boundaries:

- roll number;
- address;
- value of land in 1998;
- value of building in 1998;
- year building was constructed.

As previously mentioned, the municipalities of Deux-Montagnes and Boisbriand were unable to provide the requested data. The study areas situated in these municipalities were therefore excluded from the study. Sainte-Marthe-sur-le-Lac, Saint-Eustache and Rosemère provided extracts of their assessment rolls, and Bois-des-Filion provided the complete roll. Sainte-Marthe-sur-le-Lac, Rosemère and Bois-des-Filion, the municipalities which had built dykes, also provided maps showing the location of the dykes and the year they were built. The municipalities expressly requested us to keep the information confidential.

2.3.2 Processing the data

The databases obtained from the four municipalities contained superfluous information. They were therefore sorted and pruned until only the five types of information listed above remained, and only for residential properties located within the study area. Whether or not a property fell within the study area was determined from the address and lot number. The result was a database containing the roll number, address, land value, building value, and building construction year for every residential property in a given study area.

Each of these databases was then divided into two parts. The first part contained information on the properties in the flood-risk zone, and the second contained information on the properties in the no-flood-risk zone. Which zone a property fell within was determined from the address and lot number, together with extensive site visits.

The two parts of each database were processed in identical fashion. For each year of construction, the total value and total number of properties built that year in the zone were obtained. The yearly totals were then added together. In this way we were able to obtain the occupance (number of properties) and economic value for each zone at the time of designation, the time of withdrawal, the time of dyking and the time of the study.

3. RESULTS

The results are given in three sets of graphs (Appendix 1). Their interpretation appears in section 4. The first set of graphs (Figures 1 to 5) gives, for each property, its value by year of construction. Trends in property values over time can thus be seen, as can differences and similarities pre- and post-designation (as well as pre- and post-withdrawal in the case of Sainte-Marthe-sur-le-Lac, Figure 1). Spatially, the figures distinguish properties in the flood-risk zone from those in the no-flood-risk zone, so that the differences and similarities between the two zones of a study area can be seen.

The second set of graphs (Figures 6 to 10) shows the changes over time in the total number and total value of properties in each of the two zones. Years of designation and withdrawal are also shown. With these graphs, spatial and temporal trends in the occupance and economic value of the floodplains can be analysed.

The third set of graphs (Figures 11 to 14) shows, by study area and zone, the proportion of current total properties which were developed before and after the year of designation (Figures 11 and 12), and the proportion of current total properties which were developed before and after the year of dyking (Figures 13 and 14). The study areas were designated and/or dyked between 1976 and 1980, and this third set of graphs shows the influence of these events on the development of property in the flood-risk zones. In order to compare development in areas without dykes to areas with dykes, the year 1978 was used as the year of dyking for Saint-Eustache and for the undyked Bois-des-Filion area. The data used for Figures 11 to 14 were taken from Tables 3 to 6 of Appendix 2.

4. DISCUSSION

The aim of the Damage Reduction Program was to contain the increase in damages arising from floods having a return period of 100 years or less. If the assumptions set out in the introduction are right, analysis should show that the number of buildings erected in the flood-risk zone since designation has been almost zero, that the proportion of the area's buildings erected in the flood-risk zone since designation is small, and that the occupance and economic value of the floodplains has virtually ceased to grow. Meanwhile the no-flood-risk zones near water bodies should have seen a marked increase in occupance and economic value. Dyking, because it creates a feeling of confidence and security, should have had the opposite effect, that is, despite flood-risk designation, these zones should have seen a strong increase in occupance and economic value. The following sections analyse the actual effects of designation and dyking on the occupance and economic value of floodplains.

4.1 Designation of floodplains

4.1.1 Impact of designation on occupance of floodplains

Over the course of the 20th century, the Greater Montreal region has seen significant development and has experienced the phenomenon of urban sprawl. The whole area surrounding the city has been developed, with a transition from agricultural and recreational to residential and commercial uses. This can be seen in every one of the study areas. The number of properties has grown constantly, as demonstrated by Figures 6-10. The trend has in no way been affected by designation. The pace of growth has been maintained in every study area except the dyked Bois-des-Filion area (Figure 9), and the slower growth here can be probably be explained by the fact that occupance was almost complete at the time of designation.

The same trend is seen in the no-flood-risk zones (Figures 6-10). The number of properties has increased regularly, and independently of the designation of the adjacent zone. Given the dissuasive function of designation, one might have predicted an increased pace of construction in the no-flood-risk zones, but observation shows the opposite to be the case. Figure 11 shows that, after designation, occupance in the flood-risk zone increased as much as (or more than) in the no-flood-risk zone.

In each municipality considered, the number of properties in the flood-risk zone grew strongly, even after designation. Between 9% and 38% of the current total properties were added after designation (Table 3). On average, the number of properties has grown 25% since designation. All the municipalities have permitted increased floodplain occupance, and have thus increased their exposure to potential flood damage.

4.1.2 Impact of designation on economic value of floodplains

There is reason to assume that designation of a floodplain will lead to a significant reduction in its economic value. Occupants of floodplains are exposed to a higher probability of experiencing a flood, and this greater risk should be reflected in lower values for property located in the floodplain, these lower values offsetting potential losses from flooding. Furthermore, the possibility of losing property during a flood, and the unavailability of compensation from insurance companies or governments (Government of Canada 1976) should push current and future occupants of a floodplain to erect buildings of lesser value.

If this were indeed the case, then the triangles on Figures 1-5 (representing property values in the no-flood-risk zones) should be above the circles (representing property values in the flood-risk zones). However as Figures 1-5 show, this is not the case. Property values in the flood-risk zones are similar to if not higher than those in no-flood-risk zones. This is especially visible on Figures 1 and 2, where the extreme values in the flood-risk zone are almost twice those in the no-flood-risk zone. Despite designation, property values have not declined. Financial incentives and higher insurance premiums were not enough to induce occupants to build properties of lower value. It may be that occupants were unaware of the risk they were taking, or that they thought society would assume the risk by compensating them for their losses.

The increase in property value was steady and did not reverse itself following designation (Figures 6-10). Table 3 shows that, in the best case, property values increased by 24% after designation, while in the worst case they more than doubled (55% increase). Exposure to potential damages due to flooding has thus been increased.

Designation did not prompt new arrivals to settle in the no-flood-risk zones. Property values in these zones did not rise more rapidly after designation (Figures 6-10); indeed in some study areas they rose less rapidly (Figures 8 and 9). Property values increased more in the flood-risk zones. Figure 12 and Table 4 show that the built-up portion after designation is larger in the flood-risk zone. This reflects more rapid growth in this zone despite designation and the restrictions which this imposes on development

4.2 Dyking of flood-risk zones

Dyking has a direct impact on damage reduction because it prevents water from entering the flood-risk zones until it reaches the height of the dyke, or the dyke breaks. Dykes were built in Sainte-Marthe-sur-le-Lac, Rosemère and Bois-des-Filion. Only in Sainte-Marthe-sur-le-Lac was this done as part of the Flood Damage Reduction Program. The dyke here , built in 1980, was designed for the 100-year flood in Lac des Deux-Montagnes. In Rosemère and Bois-des-Filion, the dykes were a municipal initiative. In Rosemère, the dyke was built in 1977-78, and the elevation of the crest is below the 100-year flood recognized by the province. In Bois-des-Filion, where the dyke was built in 1976-77, the elevation varies from place to place and is unknown. In the undyked study areas (Saint-Eustache and Bois-des-Filion), 1978 was selected as the year of dyking in order to be able compare development there with development in the other study areas.

4.2.1 Impact of dyking on occupance of floodplains

The trend toward a growing number of properties in the flood-risk zones was in no way interrupted by dyking (Figures 6, 8 and 9). In the late 1980s, growth accelerated in the dyked flood-risk zones, but the same was true in the undyked areas (Figures 7 and 10); such accelerated growth was probably due to economic, demographic or other factors. Figure 13 shows that the undyked Bois-des-Filion study area saw greater development of its flood-risk zone after 1978 (27%) than did the dyked study area of this same municipality (18%). Also, as Table 5 shows, the undyked Saint-Eustache study area saw as much development in its flood-risk zone (37%) as the Rosemère area (38%) and the Sainte-Marthe-sur-le-Lac area (26%). Occupance grew as rapidly in the undyked study areas as in the dyked areas. Thus the results do not show that the presence of a dyke has an effect on the occupance of a floodplain.

4.2.2 Impact of dyking on economic value of floodplains

Dyking does not seem to affect the economic value of the floodplains. In every study area, the trend toward increased property values was in no way interrupted by dyking (Figure 1-5). The same is true of the total value of all properties (Figures 6-10). Figure 14 and Table 6 show that, in terms of value, from 26 to 55% (average 37%) of the total current properties in the dyked study areas were built after dyking. In the undyked areas, the figure was between 36 and 46% (average 41%). Thus the dyked areas have not seen more growth than the undyked areas since the dykes were built. As with occupance, economic value has not been affected by dyking.

5. CONCLUSION

Analysis of the study's results answers certain questions about the effectiveness of designation, mapping and dyking of floodplains in reducing flood damages.

First, the pace of home construction is the same (or greater) in flood-risk zones as it is in no-flood-risk zones. The same is true of property values, and it is not unusual to find homes with markedly greater values in a flood-risk zone. This means a considerably increased exposure to potential flood damage—contrary to the principle underlying the activities of designation, mapping and dyking. The long list of automatically exempted undertakings in the Canada-Quebec Agreement, as well as the withdrawal clauses in the Agreement, have allowed municipalities to pursue existing development. This point has not been considered in the present study, because it does not fall under the initial objectives, but a study should be initiated.

Second, dyking has had no effect on occupance or property values in the floodplains. The increase in occupance in dyked areas is similar to that in undyked areas, or slightly less—probably because dykes are only constructed in places that are already built-up. A dyke gives a feeling of (possible false) security. We found marked differences in the methods and quality of dyke construction. The state of the dykes, and their maintenance, were also highly variable. There may be an increased risk of erosion, sooner or later, if the dykes are poorly managed.

The study was conducted on several square kilometres of floodplain located within the boundaries of six municipalities covering about fifty kilometres of shoreline along two bodies of water. However this is a very small geographical area, in terms of Quebec or Canada as a whole. The study reflects the management practices of only a small number of municipal decision-makers, and the motivations of a small number of occupants. Other studies have been made elsewhere in Quebec and Canada, and certain parallels can be seen.

Increased exposure to flood risk has also been observed elsewhere in Quebec. Bouillon *et. al.* (1999) have noted such an increase near the Chateauguay River, specifically in the municipalities of Huntingdon, Ormstown and Gogmanchester. They explain this by growing occupance of the flood-risk zone.

Roy (1997) has looked at the occupance and economic value of the floodplains of six municipalities in the Chaudière River watershed. His study shows that in each one of these municipalities, total property value increased after designation. The increase was between 5.7 and 64.3%, with an average of 8.7%. Recently, one municipality even allowed a commercial park to be built in its flood-risk zone. This watershed is thus seeing increased exposure to flood risk and damage despite have being designated 20 years ago.

Christin (1997) has prepared a report on the flood-risk mapping program from the point of view of Quebec users. Of the 25 municipalities he questioned, 18 said they have experienced strong development pressure and 23 allow development in the floodplain. Christin found that most municipal regulations allow construction of new buildings in floodplains, though they do impose certain conditions related to flood-proofing and the presence of utilities.

To sum up the picture in Quebec: municipalities have permitted and continue to permit an increase in occupance and economic value in their floodplains. As a result, local populations are more exposed to flooding and the resulting potential for damage.

Elsewhere in Canada, research has arrived at similar conclusions. Morris-Oswald *et al.* (1998) report that urban development has increased near the Red River, upstream from Winnipeg, despite this being a highly flood-prone region. They explain this by a renewed attraction and a false sense of security arising from the presence of a floodway. Shrubsole *et al.* (1995, 1997) also find increased occupance of floodplains in the basins of the Thames and Credit Rivers in Ontario. As in Quebec, urban development on floodplains increases exposure to flooding and potential damage.

The federal Flood Damage Reduction Program mentions two types of flood-risk zone: high-velocity zones (which can be inundated by a flood having a return period of 0 to 20 years) and low-velocity zones (which can be inundated by a flood having a return period between 20 and 100 years). The elevations used to identify the boundaries of these zones are those calculated for the 20-year and 100-year floods (Rousselle *et al.* 1990). These elevations and designated zones are used in municipal regulations governing construction and renovation. They are also used as references by governments when applying bilateral agreements stemming from the Flood Damage Reduction Program.

The elevations and return periods are valid only if hydrological conditions in the watershed have not changed and the water body is not being regulated. It appears that with many water bodies, especially those in highly urbanized areas, rapid development has changed the regime of watersheds. In addition, water bodies have been harnessed for hydroelectric and other purposes. And elevations have sometimes been established without considering damage reduction measures that had already been in place for some time, for example the dykes on the banks of Lac des Deux-Montagnes and Rivière des Mille-Iles, and the Grand Moulin dam where the Lac des Deux-Montagnes flows into the Rivière des Mille-Iles (Comité sur la régularisation des eaux - Région de Montréal 1976; Pelletier 1981). The main function of the Grand Moulin dam is to reduce the flow in the Rivière des Milles-Iles. As a result the lake level, and the flows in the Rivières des Prairies and at the Sainte-Anne and Vaudreuil outlets, may well increase. The 20-year and 100-year elevations do not allow for this. Calculating high-water probabilities without considering the ways control structures are managed, or the risk that the structures will fail, is a dangerous practice. It falsifies the return periods for high-water levels, and increases the risk that dykes will overflow. Studies are needed to obtain a clear picture of the hazards present when water bodies are regulated.

In summary, the results of this study show that, as in other regions of Canada, flood damage reduction measures based on designation and mapping of floodplains have had no impact on occupance, have failed to reduce flood damages, and have not even halted increases in such damages.

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APPENDIX 1. FIGURES

Figures showing changes in occupance and economic value in floodplains and in adjacent zones not vulnerable to flooding.

Figure 1 Value of properties in Sainte-Marthe-sur-le-Lac
Figure 2 Value of properties in Saint-Eustache
Figure 3 Value of properties in Rosemère
Figure 4 Value of properties in Bois-des-Filion (dyked area)
Figure 5 Value of properties in Bois-des-Filion (undyked area)
Figure 6 Changes in number and total value of properties in Sainte-Marthe-sur-le-Lac
Figure 7 Changes in number and total value of properties in Saint-Eustache
Figure 8 Changes in number and total value of properties in Rosemère
Figure 9 Changes in number and total value of properties in Bois-des-Filion (dyked area)
Figure 10 Changes in number and total value of properties in Bois-des-Filion (undyked area)
Figure 11 Proportions of total current properties erected before and after designation
Figure 12 Proportions of total current value for properties erected before and designation
Figure 13 Proportions of total current properties erected before and after dyking
Figure 14 Proportions of total current value for properties erected before and dyking

Figure 1. Value of properties in Sainte-Marthe-sur-le-Lac

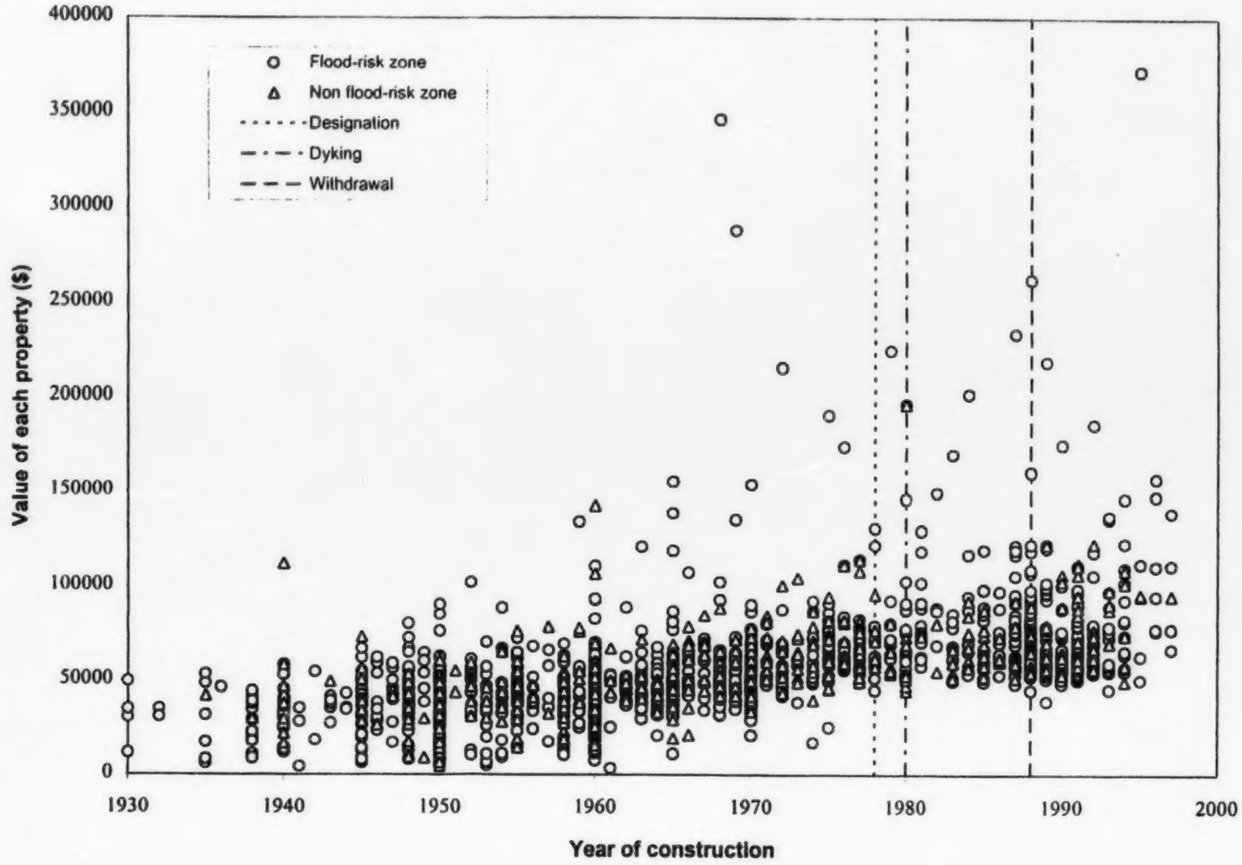


Figure 2. Value of properties in Saint-Eustache

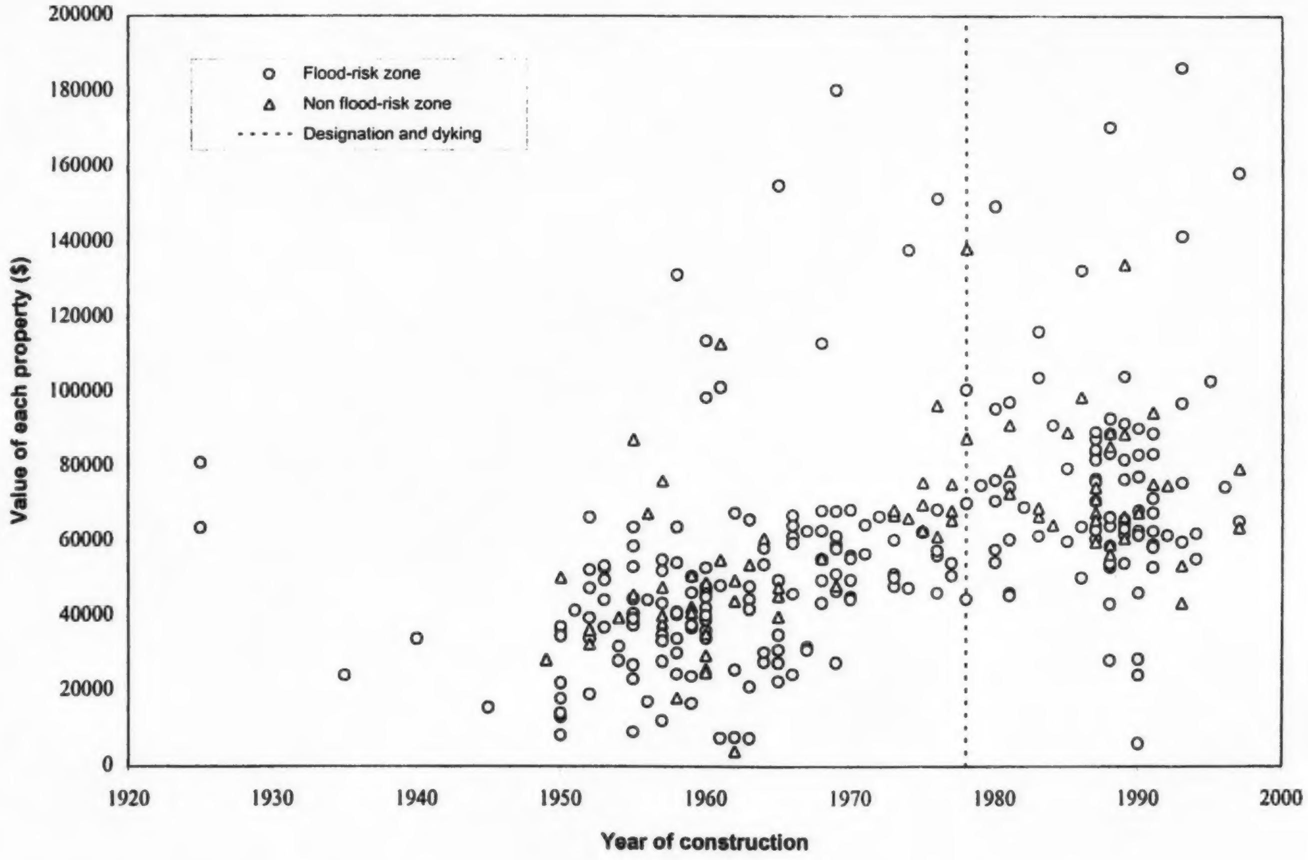


Figure 3. Value of properties in Rosemère

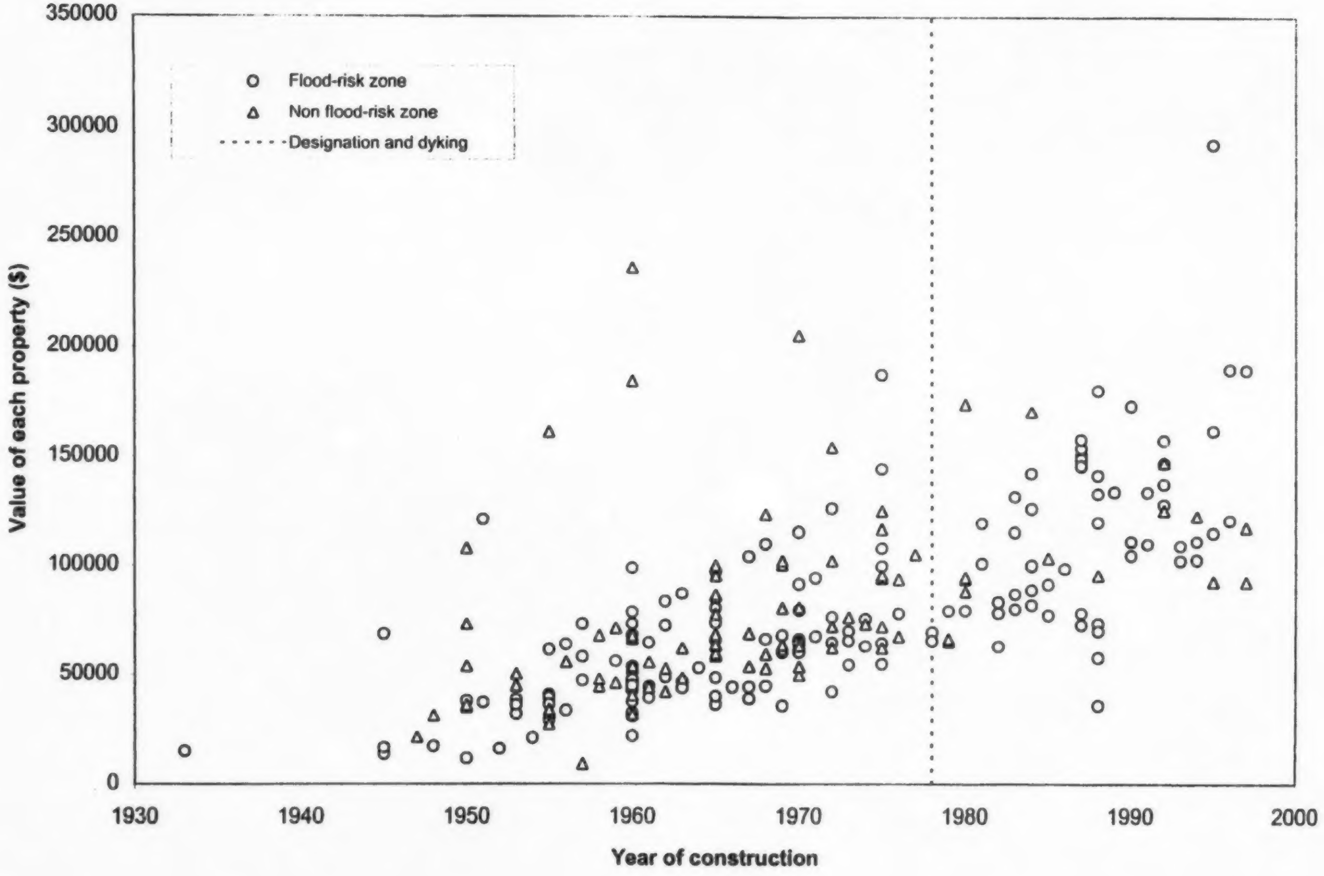


Figure 4. Value of properties in Bois-des-Filion (dyked area)

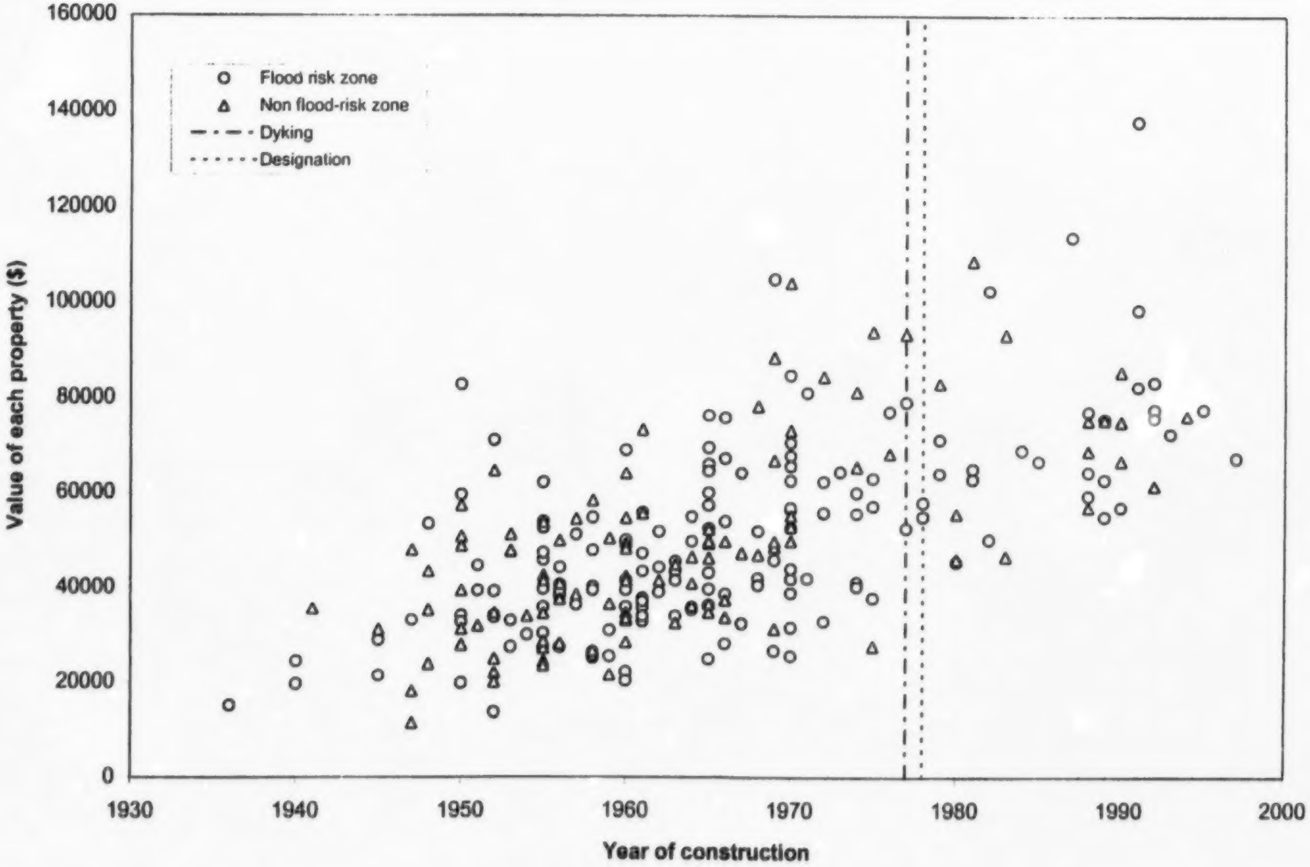


Figure 5. Value of properties in Bois-des-Filion (undyked area)

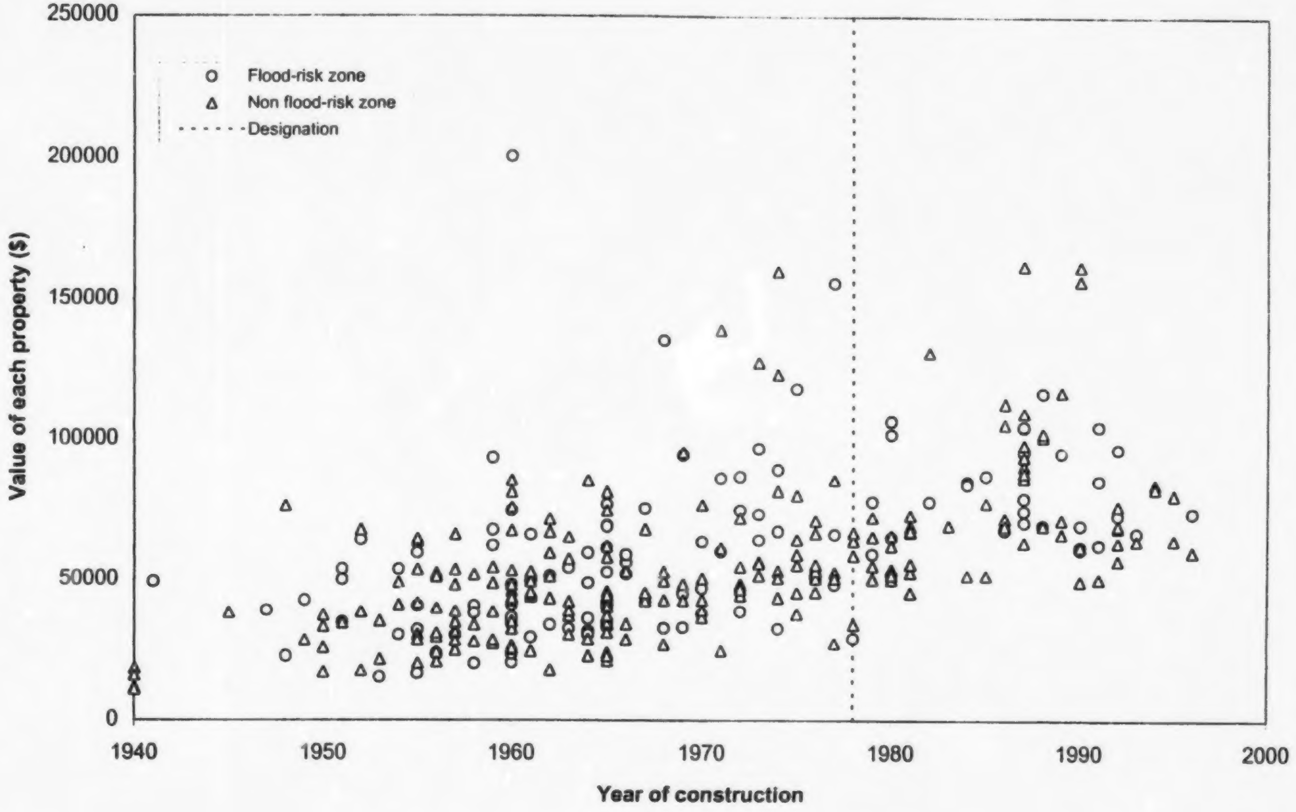


Figure 6. Changes in number and total value of properties in Sainte-Marthe-sur-le-Lac

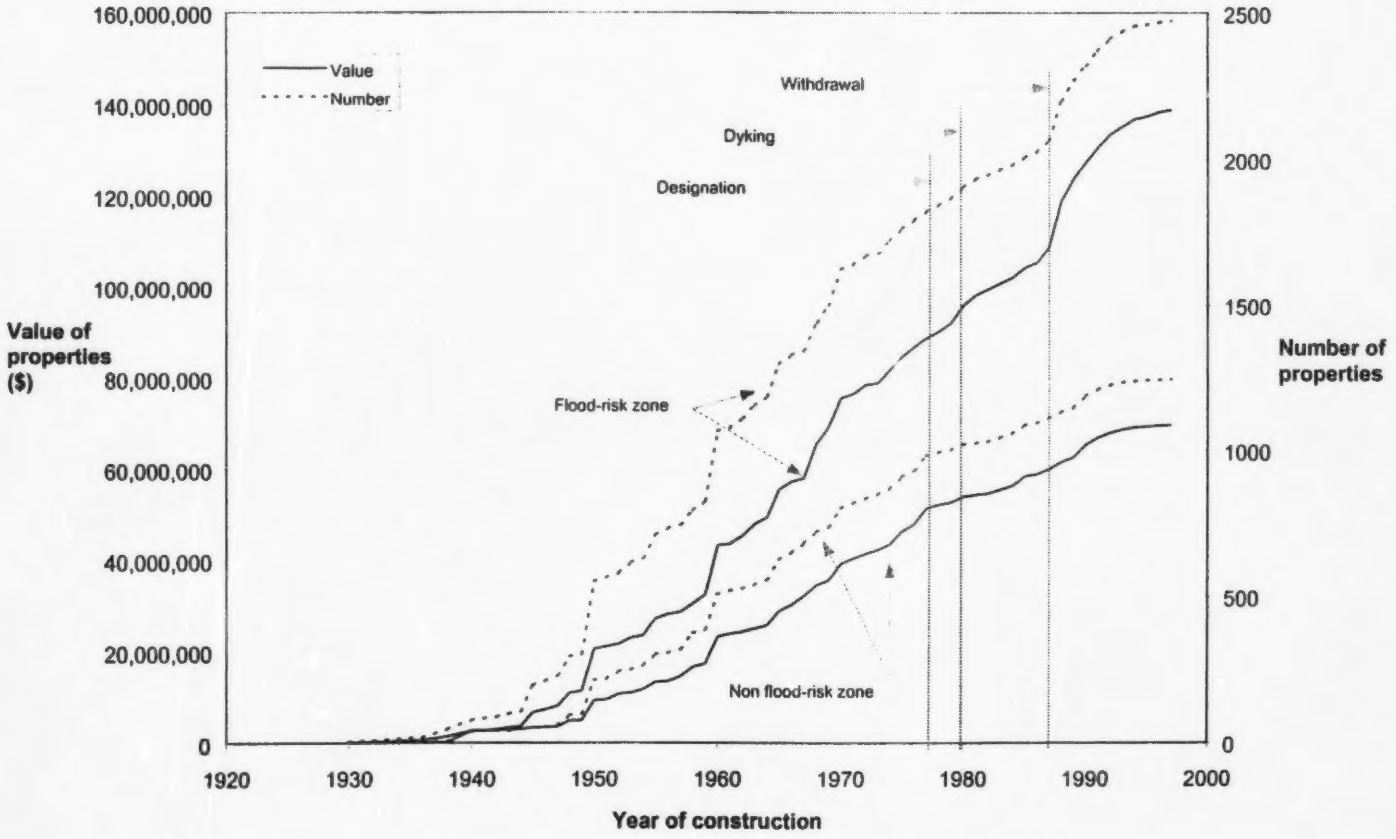


Figure 7. Changes in number and total value of properties in Saint-Eustache

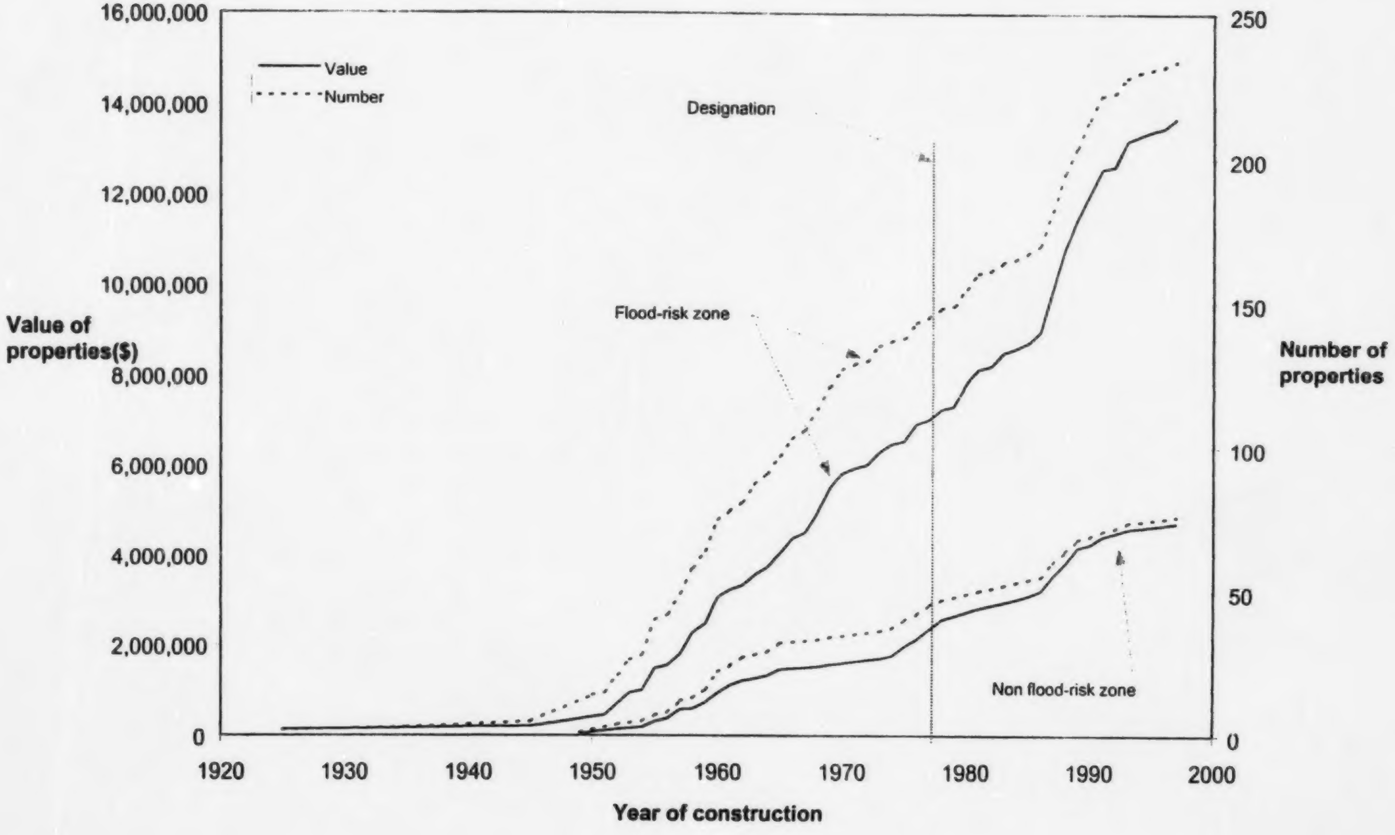


Figure 8. Changes in number and total value of properties in Rosemère

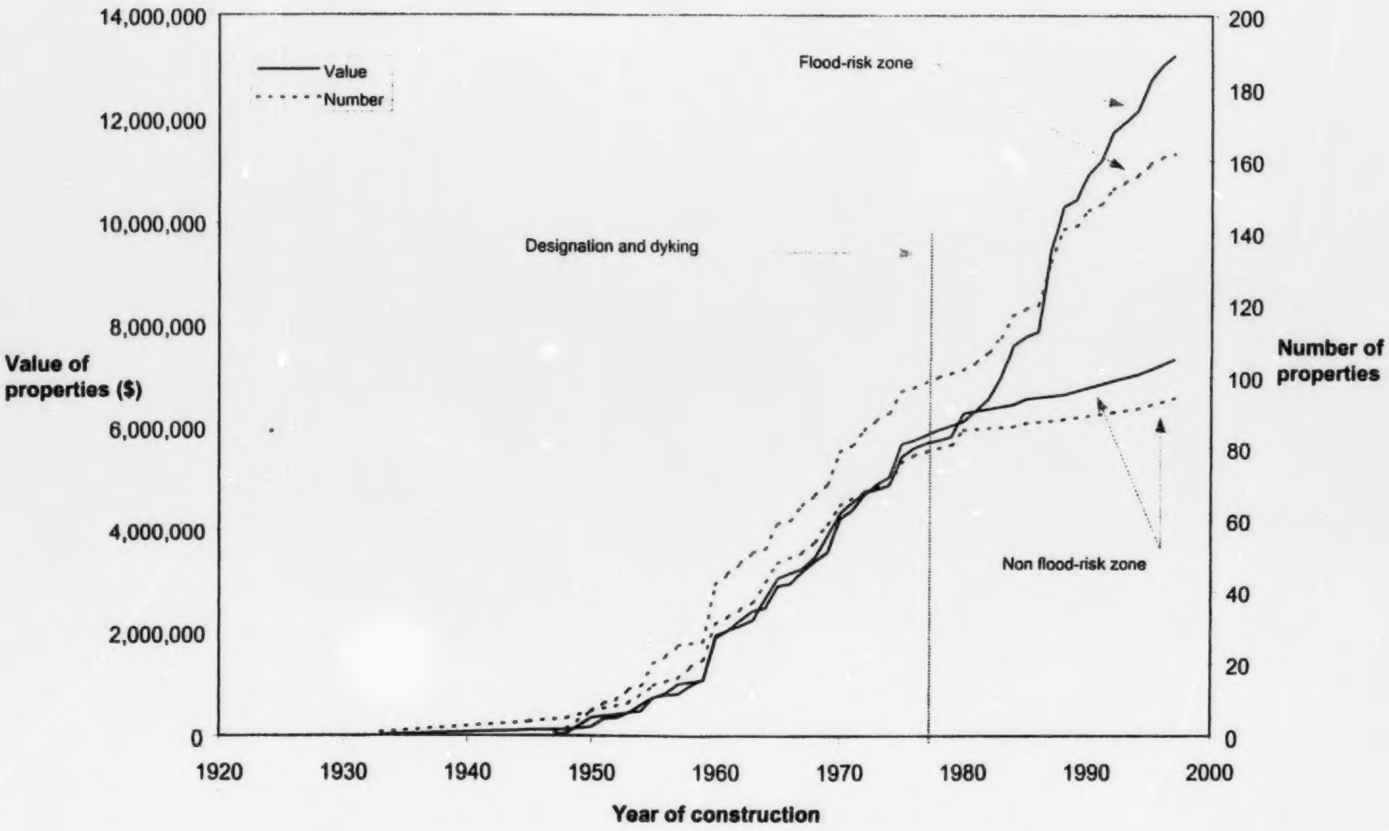


Figure 9. Changes in number and total value of properties in Bois-des-Filion (dyked area)

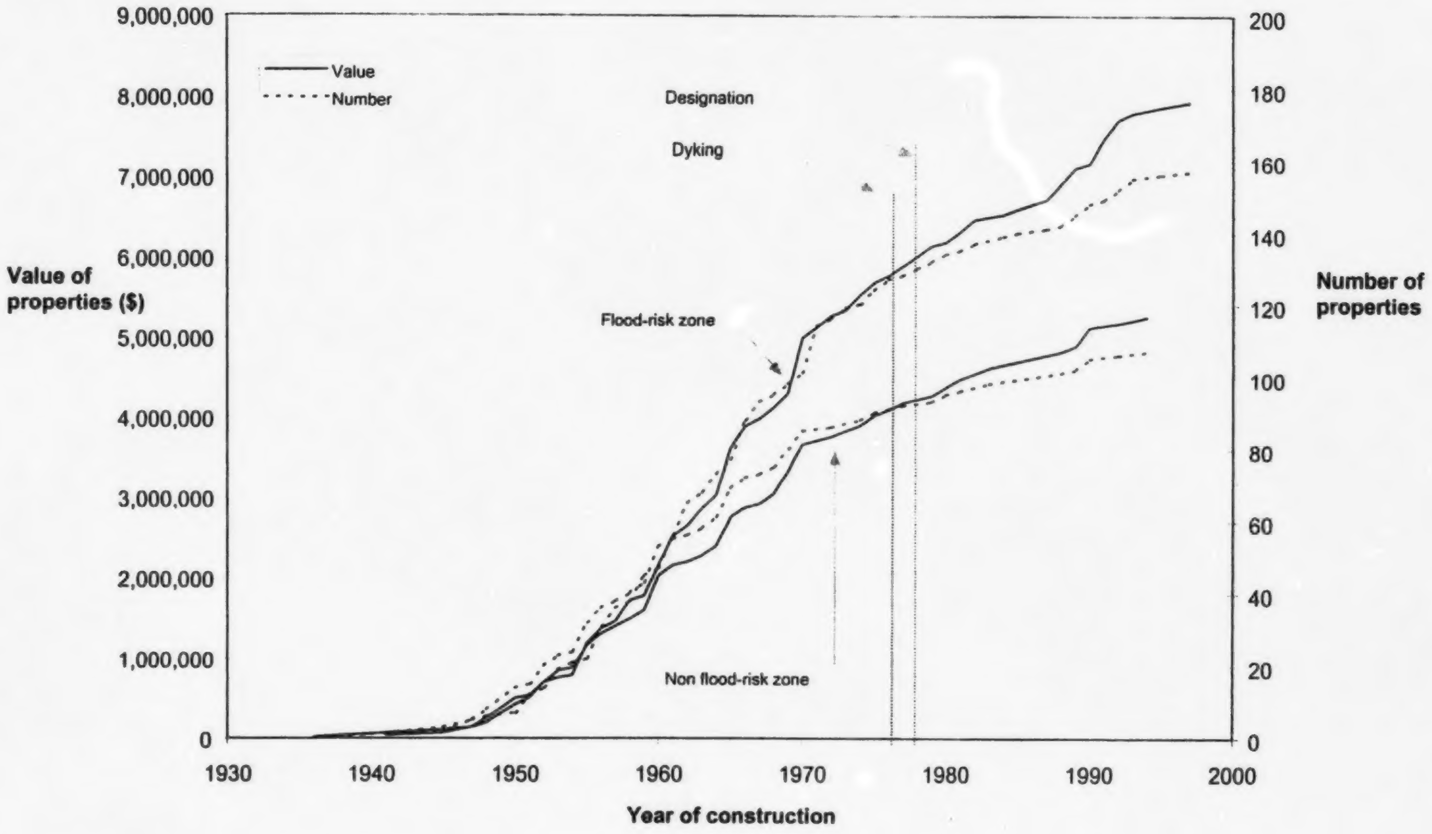


Figure 10. Changes in number and total value of properties in Bois-des-Filion (undyked area)

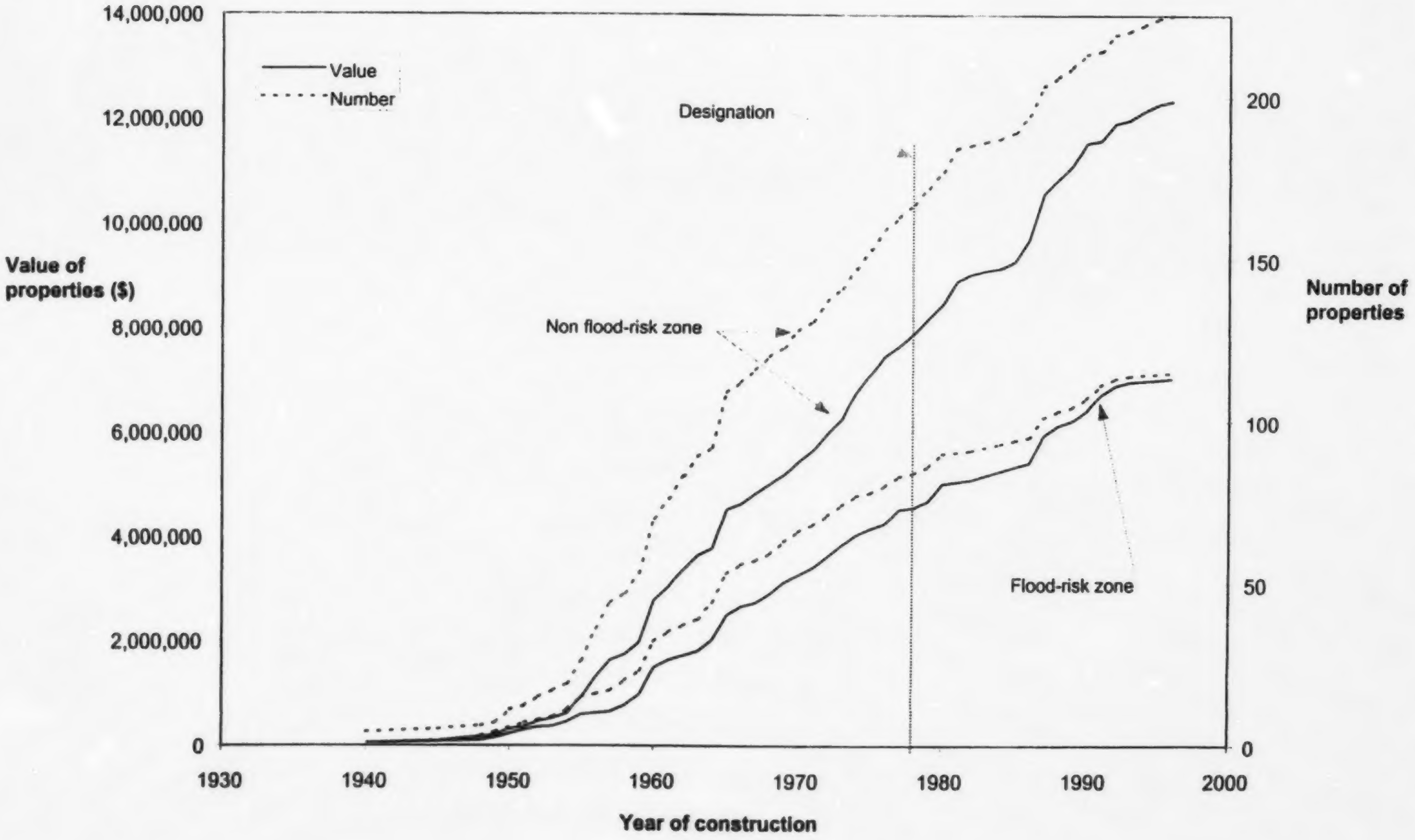


Figure 11. Proportions of total current properties erected before and after designation

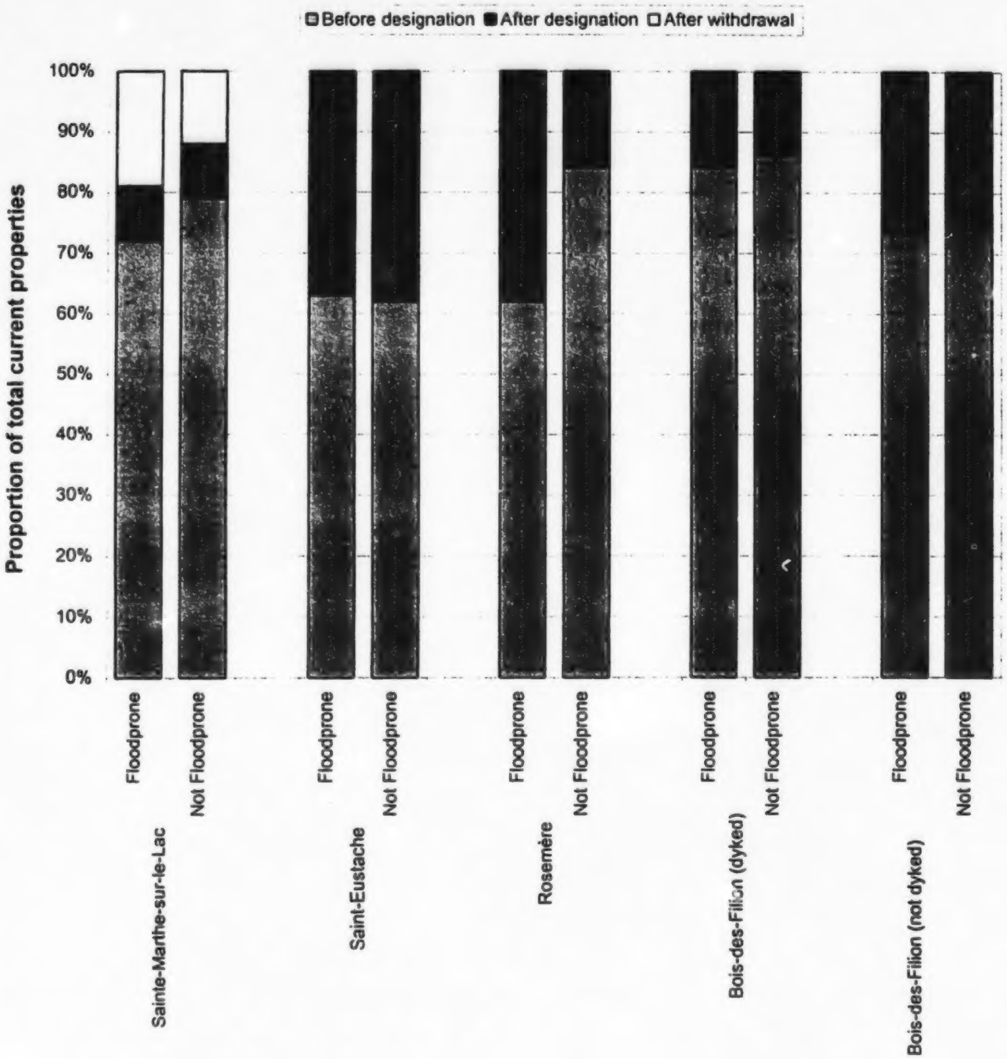


Figure 12. Proportions of total current value for properties erected before and designation

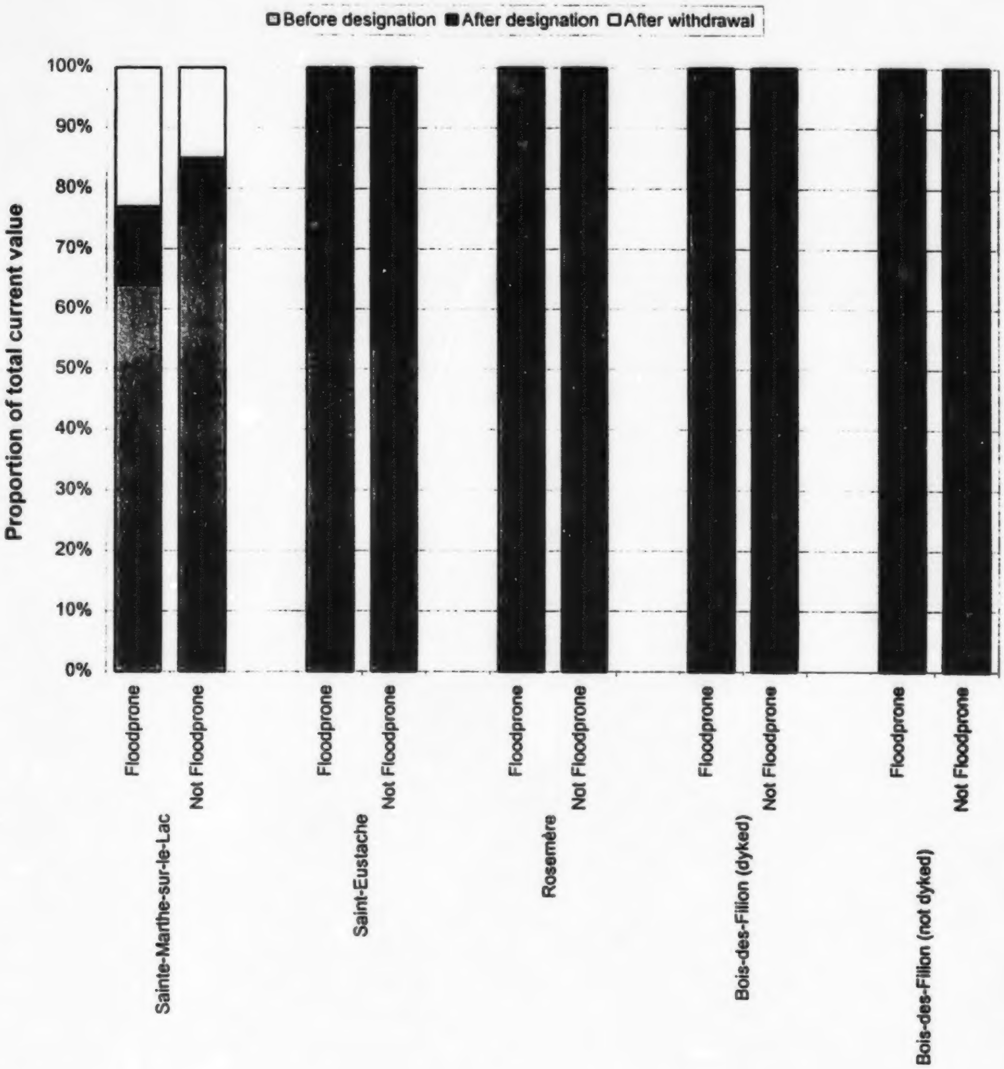


Figure 13. Proportions of total current properties erected before and after dyking

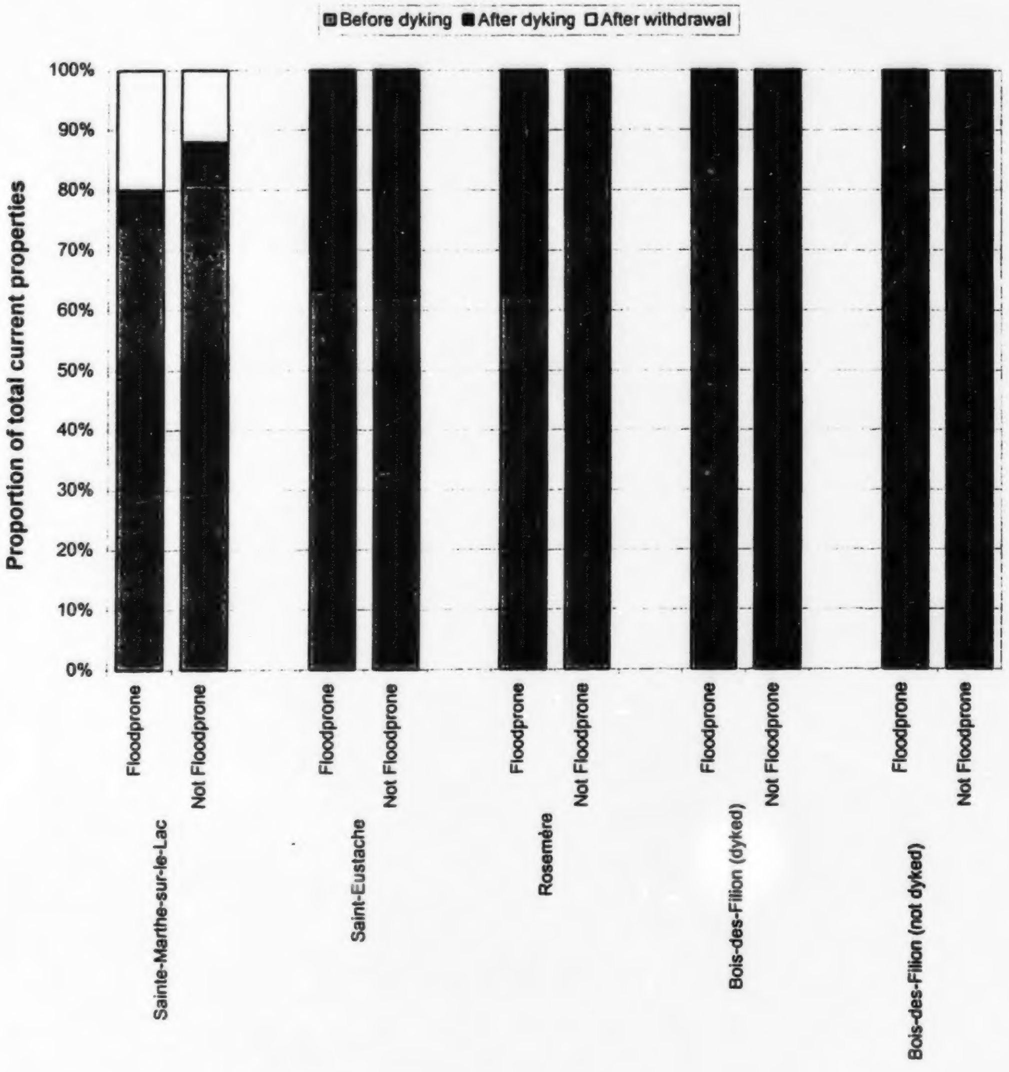
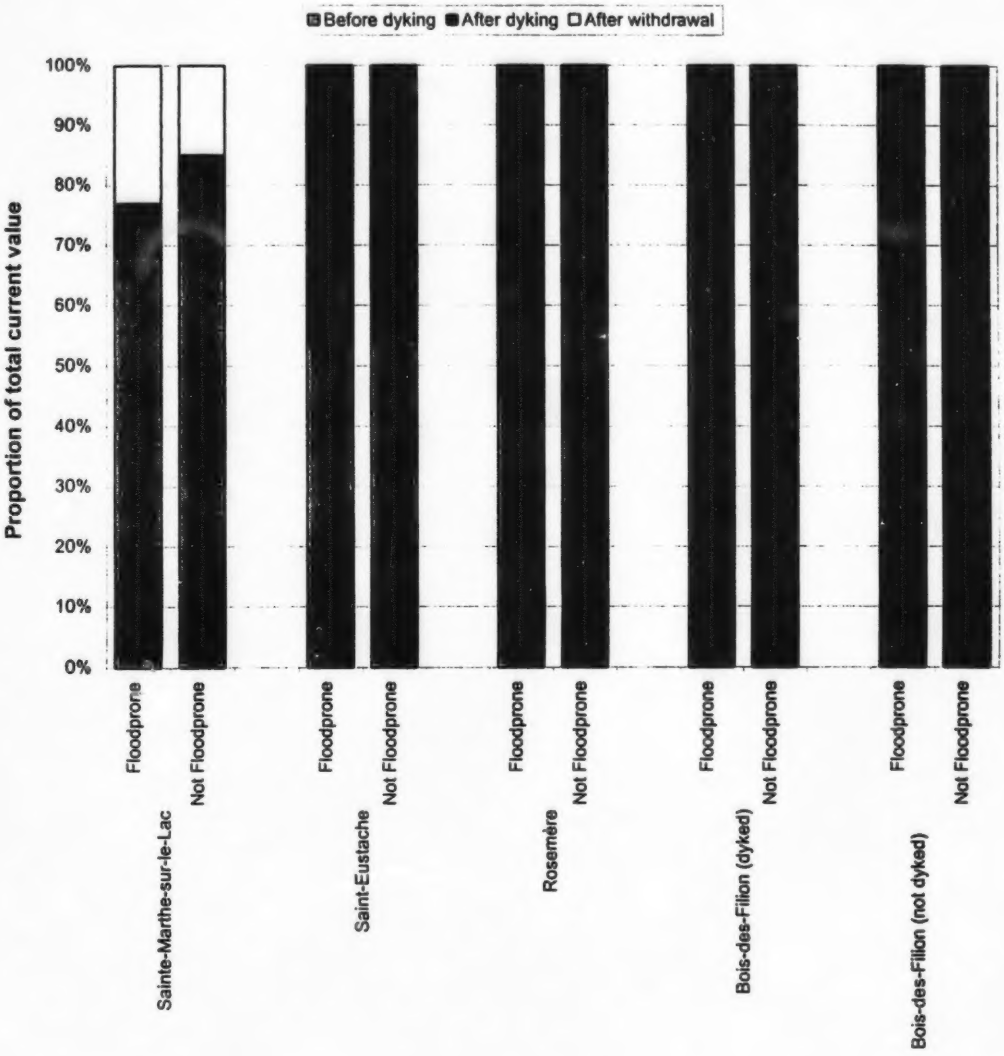


Figure 14. Proportions of total current value for properties erected before and dyking



APPENDIX 2. TABLES

Tables showing changes in occupance and economic value in floodplains and in adjacent zones not vulnerable to flooding.

Table 3	Proportions of total current properties erected in flood-risk zones before and after designation
Table 4	Proportions of total current properties erected in no-flood-risk zones before and after designation
Table 5	Proportions of total current properties erected in flood-risk zones before and after dyking
Table 6	Proportions of total current properties erected in no-flood-risk zones before and after dyking

Table 3: Proportions of total current properties erected in flood-risk zones before and after designation

Municipality	Item	Before designation	After designation	After withdrawal
Sainte-Marthe-sur-le-Lac	Number	72%	9%	20%
	Value	*64%*	*13%*	*23%*
Saint-Eustache	Number	63%	37%	
	Value	*53%*	*47%*	
Rosemère	Number	62%	38%	
	Value	*45%*	*55%*	
Bois-des-Filion (dyked)	Number	84%	16%	
	Value	*76%*	*24%*	
Bois-des-Filion (undyked)	Number	73%	27%	
	Value	*65%*	*35%*	

Table 4: Proportions of total current properties erected in no-flood-risk zones before and after designation

Municipality	Item	Before designation	After designation	After withdrawal
Sainte-Marthe-sur-le-Lac	Number	79%	9%	12%
	Value	*74%*	*11%*	*15%*
Saint-Eustache	Number	62%	38%	
	Value	*54%*	*46%*	
Rosemère	Number	84%	16%	
	Value	*78%*	*22%*	
Bois-des-Filion (dyked)	Number	86%	14%	
	Value	*80%*	*20%*	
Bois-des-Filion (undyked)	Number	74%	26%	
	Value	*64%*	*36%*	

Table 5: Proportions of total current properties erected in flood-risk zones before and after dyking

Municipality	Item	Before dyking	After dyking	After withdrawal
Sainte-Marthe-sur-le-Lac	Number	74%	6%	20%
	Value	*68%*	*9%*	*23%*
Saint-Eustache	Number	63%	37%	
	Value	*53%*	*47%*	
Rosemère	Number	62%	38%	
	Value	*45%*	*55%*	
Bois-des-Filion (dyked)	Number	82%	18%	
	Value	*74%*	*26%*	
Bois-des-Filion (not dyked)	Number	73%	27%	
	Value	*65%*	*35%*	

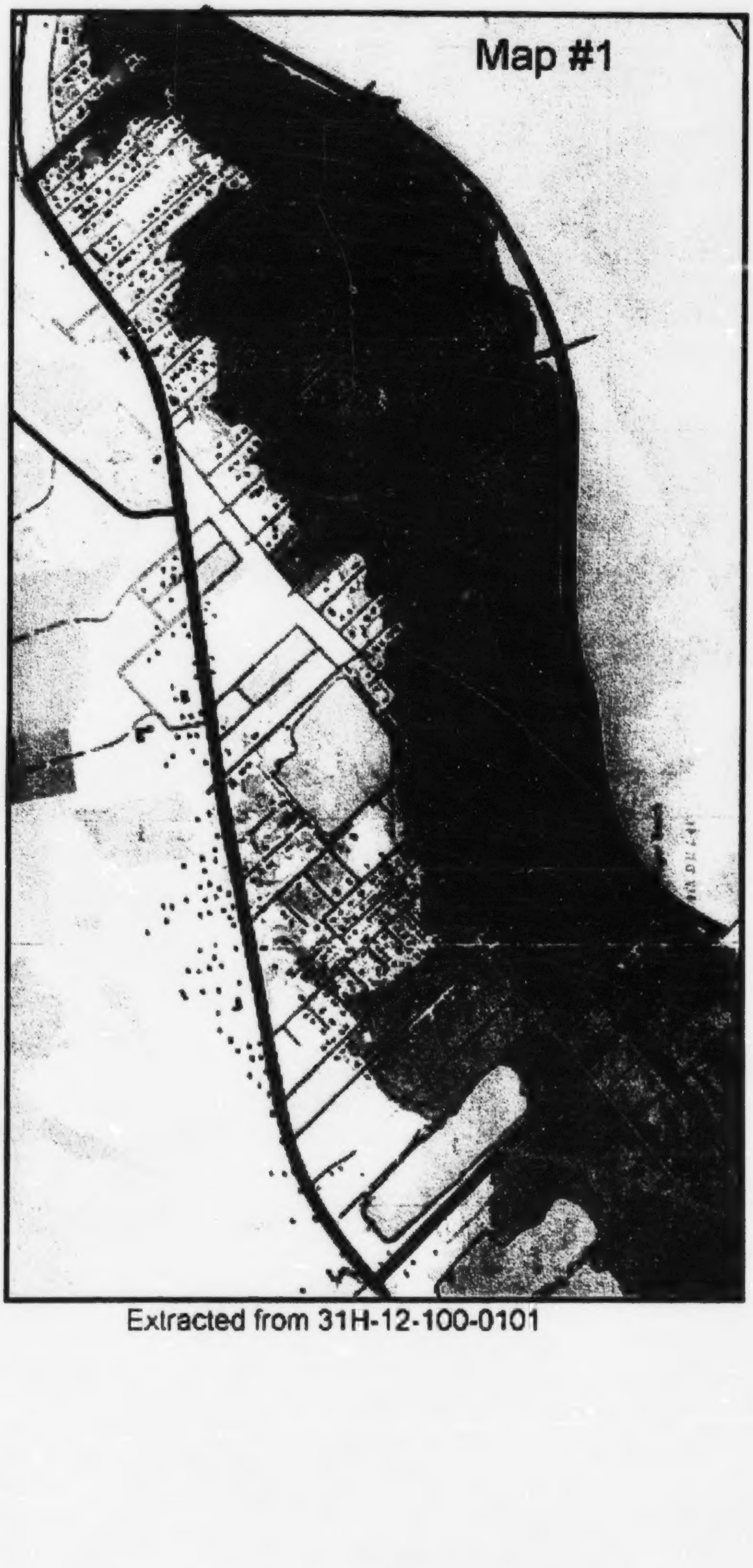
Table 6: Proportions of total current properties erected in no-flood-risk zones before and after dyking

Municipality	Item	Before dyking	After dyking	After withdrawal
Sainte-Marthe-sur-le-Lac	Number	81%	7%	12%
	Value	*77%*	*9%*	*15%*
Saint-Eustache	Number	62%	38%	
	Value	*54%*	*46%*	
Rosemère	Number	84%	16%	
	Value	*78%*	*22%*	
Bois-des-Filion (dyked)	Number	86%	14%	
	Value	*80%*	*20%*	
Bois-des-Filion (not dyked)	Number	74%	26%	
	Value	*64%*	*36%*	

APPENDIX 3. GEOGRAPHICAL LOCATION OF STUDY AREAS

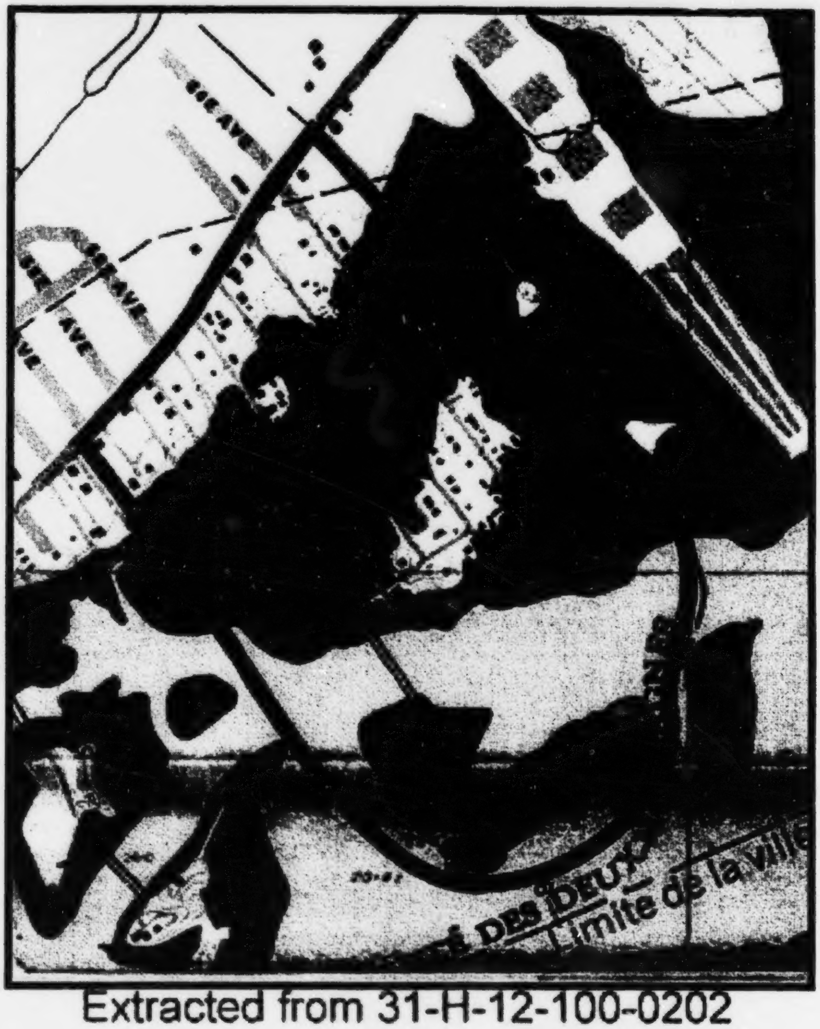
Map 1	Extract of topographical map 31H 12-100-0101 showing the Sainte-Marthe-sur-le-Lac study area.
Map 2	Extract of topographical map 31H 12-100-0202 showing the Saint-Eustache study area.
Map 3	Extract of topographical map 31H 12-100-0302 showing the Rosemère study area.
Map 4	Extract of topographical map 31H 12-100-0302 showing the dyked Bois-des-Filion study area. Two areas are shown. Since they are small, and both are located within the municipality's boundaries, they have been joined to form a single area.
Map 5	Extract of topographical map 31H 12-100-0302 showing the undyked Bois-des-Filion study area. Two areas are shown. Since they are small, and both are located within the municipality's boundaries, they have been joined to form a single area.

Sainte-Marthe-sur-le-Lac



Extracted from 31H-12-100-0101

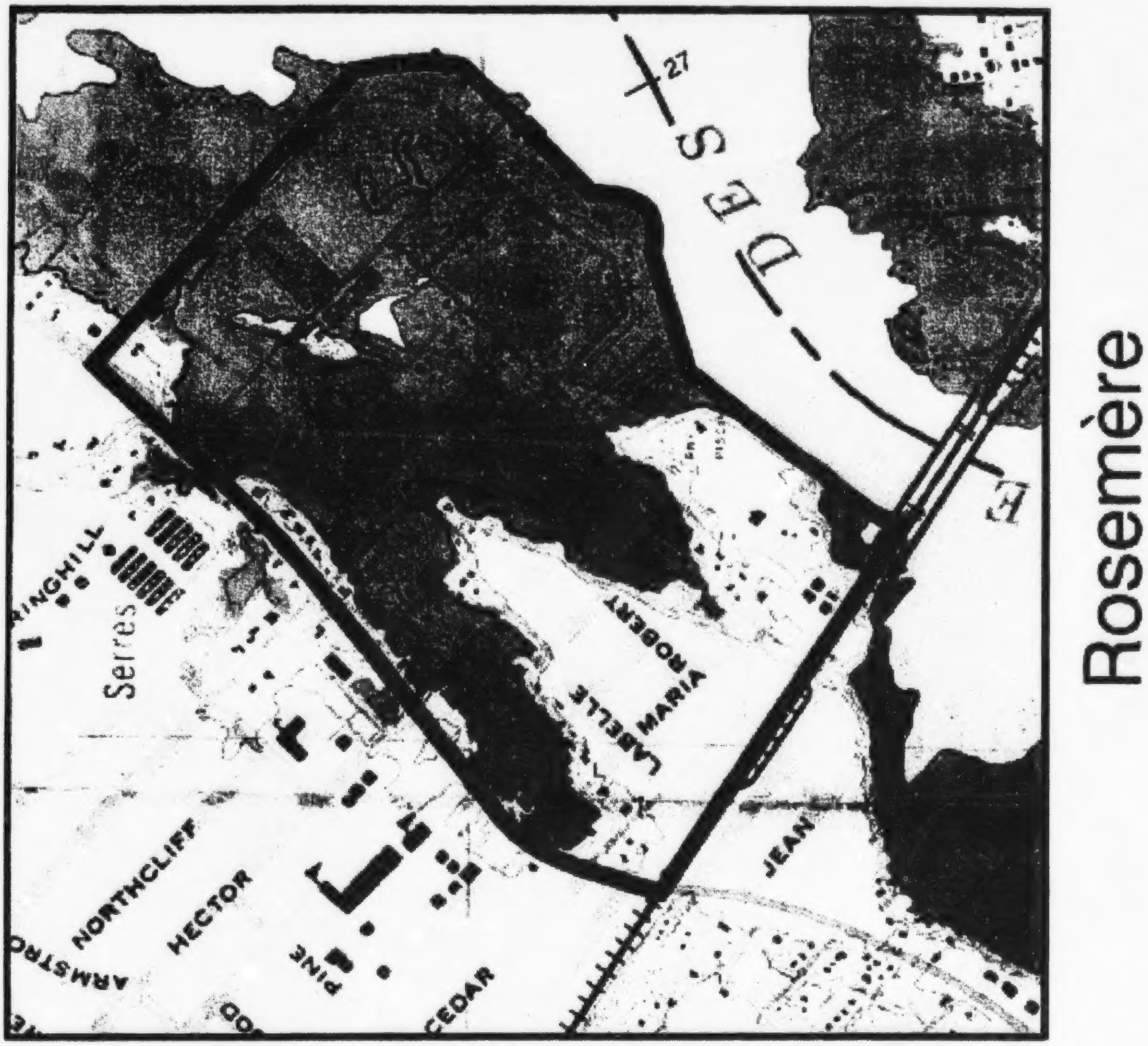
Map #2



Extracted from 31-H-12-100-0202

Saint-Eustache

Map #3



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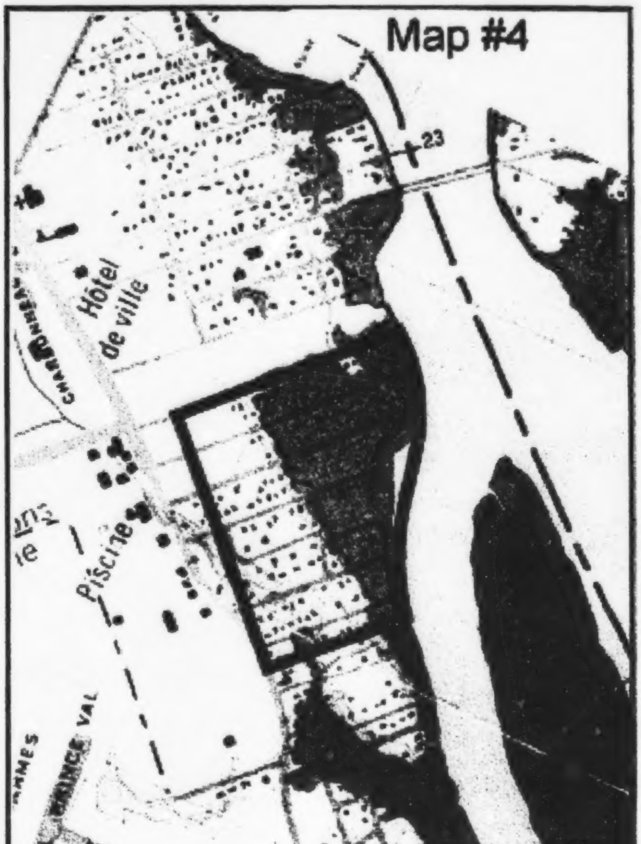
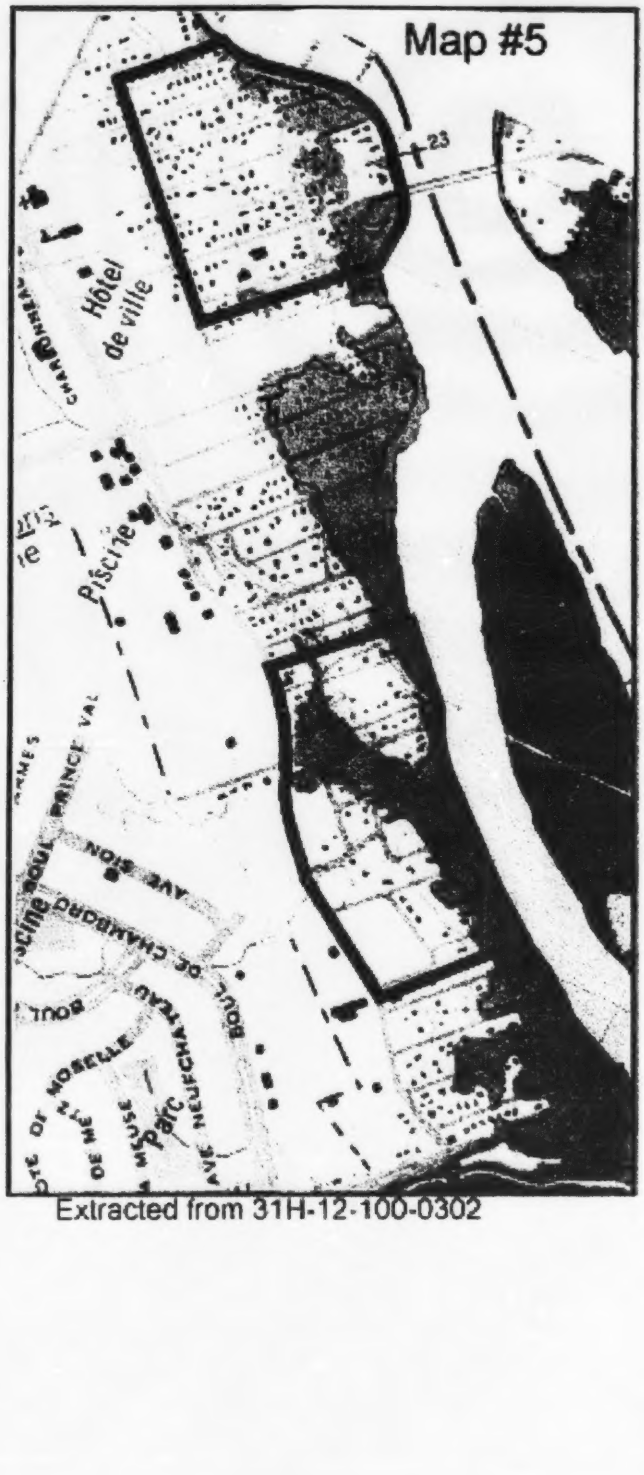


Bois-des-Filion

Extracted from 31H-12-100-0302



Extracted from 31H-12-100-0302

Bois-des-Filion